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International Irrigation Management Institute

Selected Research Highlights

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New Vision for IIMI

In 1995, the International Irrigation Management Institute (IIMI) substantially changed direction and management. Increasing the productivity of irrigated agriculture remains the focus of IIMI's work, but this objective is now approached in the context of water basins and the analysis of water resource systems as a whole. IIMI's underlying values have not changed—the institute remains committed to designing and carrying out research activities to help the world's poorest people make lasting improvements in their lives. IIMI will continue to explore methods that help to alleviate poverty, protect and conserve the environment, and ensure that women have full and equal access to resources.

Most of the world's population and economic activity are located in twenty or so large water basins. The annual renewable supply of water in these water basins is essentially fixed. As population and economic growth occur against this fixed supply of water, competition and conflicts among agricultural, urban, industrial, and environmental users will intensify.

Historically, rising demand for water has been met through developing additional water supplies by controlling rivers and building canals and other conveyance facilities. But the best sites for water development have already been utilized in most countries and further development is increasingly expensive. The world is entering a new era of water management that requires improved physical and economic productivity of water use in addition to water development programs.

IIMI is taking a leading role in this new era by helping people to use water more productively and by finding ways to design and implement more sustainable water development programs. IIMI's approach is to work at the intersection of policies, technology, and institutions.

The magnitude of the challenge in the new era of water management should not be underestimated. It is commonly thought, for example, that existing uses of water, especially in irrigation, are so inefficient that even small improvements in water use efficiency would generate large amounts of additional water supply. While this is true in some cases, it needs to be critically examined in others. For example, water "wasted" in one part of a water basin or river basin can be recaptured and used in another part. In such cases, one user's drainage is another user's water supply. And if the user increases his or her efficiency of water use, thereby reducing drainage, the downstream user's water supply is reduced correspondingly. At a broader level of analysis, inefficient surface irrigation systems often recharge aquifers on which the highly productive tube-well systems thrive.

As these examples show, the macro-efficiency of the water basin as a whole can be high even though the micro-efficiency of individual units within the basin is low. Thus, in considering water use efficiency, it is important to distinguish between "real" water savings as opposed to "paper" water savings. Because drainage water is usually recycled, water quality—negatively affected by pollutants entering the water system and positively affected by water treatment—is as important as water quantity. The need to enhance water productivity and maintain water quality requires new and creative approaches to water policy, institutions, and technologies. A wide range of options must be considered. A significant shift toward tube-wells is already underway in many regions. The use of pressurized (sprinkler and drip) irrigation systems can increase yields by 20 to 30 percent over surface irrigation through better water control and, hence, better plant-fertilizer-water interactions. In sum, IIMI is both broadening its approach, paying attention to competition for water at the water basin level, and deepening its analysis, through attention to those technical improvements in irrigation that result in increased productivity of water.

It is IIMI's intention to become a world leader in this new era of irrigation and water resource management but because of limited core funds, IIMI's development capacity, providing technical assistance, has expanded more rapidly than its research capacity. Now, IIMI is focusing on bringing its research capacity up to international standards and providing intellectual leadership in the field of irrigation and water resource management.

IIMI believes that sound decisions can only be based on rigorously tested concepts. There are many interesting and exciting theories and hypotheses which need to be tested through detailed empirical and quantitative analyses of the facts. Consequently, IIMI is focusing on state-of-the-art measurement technologies—from remote sensing to field-level instrumentation—and increasing its capacity in data analysis and computer simulation models.

To ensure that state-of-the-art knowledge is brought to bear on the problems, IIMI has established a global network of leading professionals in the field of water resource management and irrigated agriculture. The network includes other international agricultural research centers, research institutions and universities throughout the world, and a number of internationally recognized authorities. Thus, in 1995, IIMI took its first steps at becoming a new kind of research and development institution—a "virtual" institution that is extending through electronic information and communication systems around the world—when it started to integrate the best minds with the most important problems in the field of water resource management and irrigated agriculture.

David Seckler
Director General

Water and Salinity Balances for Sustainable Irrigated Agriculture in Pakistan

In certain environments, the sustainability of agricultural production is critically dependent on the prevailing irrigation and agronomic practices. The value of information that can be obtained from a water and salinity balance analysis of an irrigation system, which can be used to guide these practices, is frequently underrated. Changing irrigation practices and management can have a considerable impact on water and salinity relationships, but attention is seldom given to collecting reliable data on the components of the water and salt balances.

Although the various sources of water—rainfall, canal water, and pumped groundwater—with their differing salt contents interact in complex ways, some reasonable, simplifying assumptions can be made to establish the water and salinity balances of entire irrigation systems or distributary command areas. The analysis of these balances can yield useful information about the potential impact of current irrigation and agronomic practices on the continued sustainability of irrigated agriculture in the system.

Until deep tube wells were introduced for vertical drainage under the Salinity Control and Rehabilitation Projects (SCARPs) in the 1960s, extensive areas in Pakistan's Punjab had shallow water tables resulting from inadequate drainage and poor irrigation practices. Over the past thirty years, more than 12,500 public tube wells have been installed under the rehabilitation project. During this time, groundwater development through the installation of private tube wells grew exponentially, especially in the Punjab.

According to the latest estimates, Pakistan now has more than 300,000 private tube wells.

A national survey undertaken in 1991 claimed that the volume of groundwater used for irrigation in the Indus Basin was around 46 billion cubic meters, of which 85 percent came from private tube wells. The total groundwater extraction exceeds the annual usable groundwater by more than 50 percent. Although the water tables declined beyond the range over which salinization, due to capillary action, could be expected, salinity continues to present a threat to the sustainability of irrigated agriculture in the Punjab because of the recycling of large quantities of poor quality groundwater.

In this study, by calculating the water and salinity balances in three different regions of Pakistan that contrast widely in water availability and salt content of the irrigation water, IIMI demonstrated how the input values of both groundwater pumping and cropping patterns could be altered to achieve sustainable irrigation and agronomic practices.

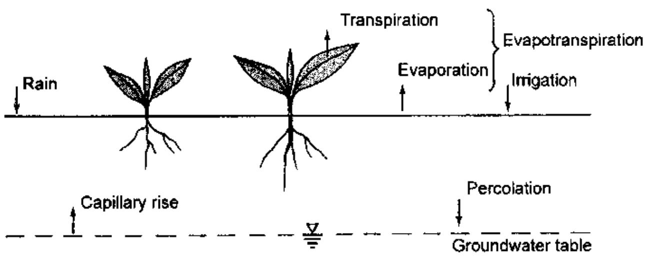
Salinity and water balance models

The water balance model takes into account two sources of water, surface-delivered supplies and rainfall, and four uses or outflows—crop evapotranspiration, nonbeneficial evaporation and transpiration, drainage runoff, and net flows to groundwater. These elements are linked through seepage from channels and irrigated fields; the disposition of rainfall among runoff, infiltration, and evapotranspiration; and two modes of internal reuse (pumping from groundwater and pumping from drains).

The model requires as input data, the area under consideration, its cropping intensity, the surface water supplies, and the effective rainfall—that portion used by the crop—over the time period under review. An extremely important figure to determine in systems where groundwater and surface water are used conjunctively, is the percentage of water going to groundwater through seepage from canals, watercourses, drains, and fields.

The model for the salinity balance is schematically presented in figure 1. The model considers the root zone as a single layer with a homogeneous distribution of water and salt. The salts are assumed to be highly soluble and not to precipitate because of saturation of the soil solution. The maximum salt concentration in the root zone is limited by the salt tolerance of the crops, and the expected yield reduction resulting from irrigation with brackish water is well documented for most commercial crops. The assumption is also made that the irrigation water is thoroughly mixed with the soil water in the root zone so that the salt concentration of the soil water at field capacity equals the salt concentration of the water that percolates from the root zone.

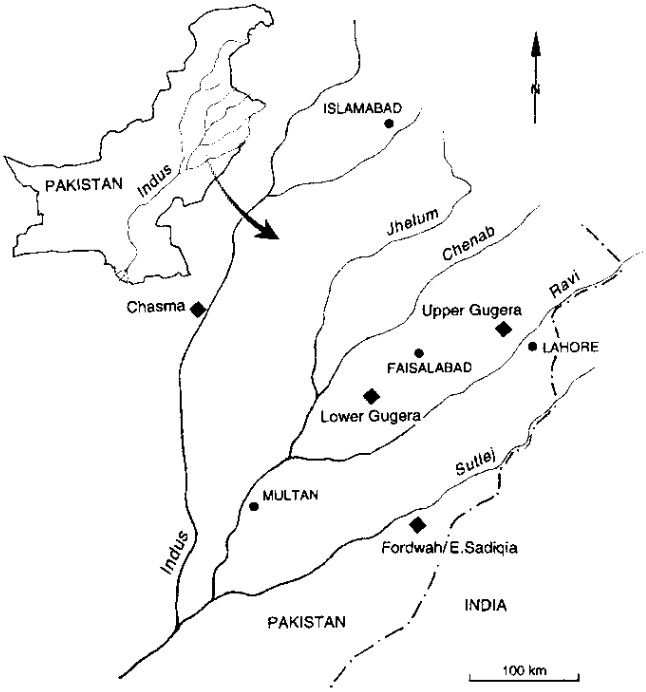
Figure 1. Components of the water balance, each of which has its own salt content.



The sites

Water and salt balances were calculated for three irrigated areas in Pakistan (figure 2) which differed in water availability, amounts of water pumped for irrigation from groundwater, and salt content of the

Figure 2. Location of the sites for the water and salinity analysis.



irrigation water. One site, located in the Chasma Right Bank Canal Project command area in the North-West Frontier Province, is currently under construction, the first stage being completed and made operational in 1987. Once completely finished, the gross command area of the system will cover around 280,000 hectares with a cultivable command area of 230,000 hectares. The second site was located in the Fordwah/Eastern Sadiqia System, southeast Punjab, commanding a gross area of 301,000 hectares with a cultivable command area of 232,000 hectares. The third site included the two command areas, the Upper and Lower Gugera Branch Canal, in the Lower Chenab Canal System which is the largest single canal system in the Punjab with a cultivable command area of around 1.2 million hectares.

Calculating the balances

The input data for the water balance calculations are presented in table 1 and are based primarily on direct observations and measurements. Significantly, the Chasma Right Bank Canal site uses only canal water for irrigation whereas the other two sites use both canal water and pumped groundwater conjunctively, but in different amounts.

Table 1. Input data for water balance calculations for the Chasma Right Bank Canal, the Fordwah Branch Canal, and the Gugera Branch Canal, for kharif and rabi seasons.

	Chasma		Fordwah		Gugera	
Parameter	kharif	rabi	kharif	rabi	kharif	rabi
Study area (ha)	19,905	19,905	67,597	67,597	27,064	27,064
Cropping intensity (%)	50	90	70	55	70	85
Canal inflow (000 m³)	123,295	145,053	389,000	115,600	68,475	80,559
Operational losses (%)	5	35	5	5	5	5
Canal seepage (%)	10	10	25	25	25	25
Watercourse seepage (%)	15	15	30	30	30	30
Field efficiency (surface) (%)	80	80	80	80	80	80
Irrigation to runoff (%)	30	30	20	20	20	20
Drain seepage (%)	10	10	30	30	30	30
Losses to nonbeneficial ET (%)	30	30	30	30	30	30
Rainfall (mm)	150	100	125	54	350	150
Effective rain (irrigated) (%)	80	80	80	80	80	80
Effective rain (unirrigated) (%)	50	50	50	50	50	50
Rain to runoff (%)	40	40	40	40	40	40
Pump recovery (groundwater) (%)	0	0	140	160	200	90
Pump recovery (drains) (%)	15	10	5	5	5	5
Field efficiency (pump) (%)	90	90	90	90	90	90

The selected results from the calculated water balances and salt balances are shown in table 2. The input for the calculation of the salt balances included the three components of water used for crop evapotranspiration—surface supplies, rainfall, and groundwater pumping—and their salt contents (expressed as electrical conductivity, EC) obtained from the water balance analysis. A fourth and smaller component was water obtained from pumping from drains. In the table, the figure given for the net flow to (positive) or from (negative) the groundwater reservoir is the difference between surface supplies and rain going to the groundwater and pumping from groundwater. The leaching fraction is the proportion of total water entering the soil profile that goes to groundwater. The calculated values of the salt for the Gugera and Fordwah sample sites were made to show the measurement of salinity and the change in salinity that occurred over the two seasons, *kharif* (summer monsoon) and *rabi* (winter). It can clearly be seen that for both these sites the net flow to groundwater is much less for kharif than for rabi. Correspondingly, salt accumulation in the soil is greater in kharif than in rabi.

Sensitivity analysis

An analysis was carried out on the water balance of the Fordwah/Eastern Sadiqia site to assess the sensitivity of the results of these calculations to the original input values. Table 3 shows that:

- Large changes occurred in the allocation of surface supplies to crop use when the input values for watercourse seepage or field efficiency for surface water were changed.
- Significant effects on the allocation of groundwater pumping to crop use resulted from changes in these two variables, and also from changes in the input values for canal seepage, losses to nonbeneficial evapotranspiration, and pump recovery.
- As allocations from pumped water increased and the allocations from surface supplies decreased, the ratio between the two soon became unrealistic.
- The effect of changes in input values on the salt balance was small.

Table 2. Selected values of water and salinity balances in the Chasma Right Bank Canal, the Fordwah Branch Canal, and the Gugera Branch Canal, for kharif and rabi seasons.

		Crop use (mm) from			Total	Non-	Net flow to	Leaching	EC (dS/m)	
Site	Season	Surface water	Rainfall	Groundwater pumping	crop use (mm)	beneficial ET (mm)	groundwater (mm)	fraction (%)	Irrigation water avg.	Change in soil water
CRBC										
	Kharif	716	120	–	855	89	207	11	–	–
	Rabi	303	80	–	409	69	160	10	–	–
Fordwah										
	Kharif	322	100	487	912	122	–256	10.1	1.53	0.4
	Rabi	122	43	228	394	41	–157	9.8	1.65	0.3
Gugera										
	Kharif	142	280	473	897	74	–353	12.8	1.93	0.4
	Rabi	137	120	139	397	62	–10	14.1	1.3	–0.2

Table 3. Sensitivity analysis for the Fordwah/Eastern Sadiqia site.

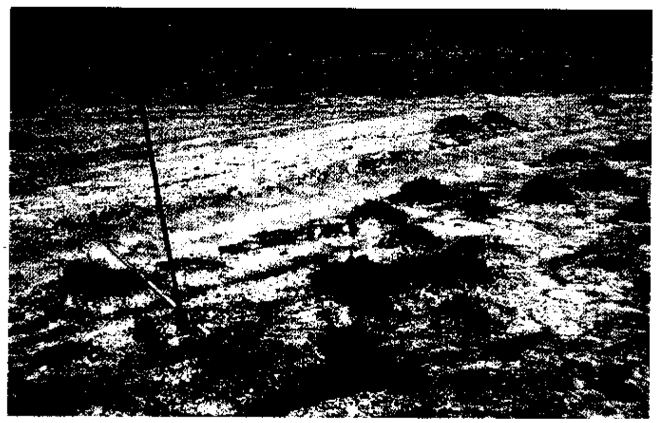
Parameter	Change in assumed input values (%)	Change (%) Crop use	From surface	From groundwater
Operational losses	0 to 10	-6	−10	-4
Canal seepage	15 to 25	−2	−10	21
Watercourse seepage	30 to 20	2	12	−24
Field efficiency (surface)	80 to 70	−3.5	-13	18
Irrigation to runoff	20 to 30	−0.7	0	−4
Drain seepage	10 to 20	0.4	0	3
Losses to nonbeneficial ET	30 to 40	3	0	-15
Effective rain (irrigated)	80 to 70	−1.5	0	6
Pump recovery (groundwater)	100 to 90	−2	0	−11
Pump recovery (drains)	15 to 5	−0.5	0	0
Field efficiency (pump)	90 to 80	−1	0	−5

- The calculated leaching fraction was not affected by a relative change in allocations from surface water and groundwater supplies so long as the field efficiencies for these supplies remained the same.

Sustainability of the systems

The choice of input values is crucial for the actual values of the various components of the water and salt balance, and the sensitivity analysis identified the most important factors to get right—canal seepage, watercourse seepage, and field efficiency for the surface supplies.

Current irrigation practices should not be continued.



In the Chasma command area, groundwater recharge was shown to be considerable and, in the absence of groundwater pumping, is bound to lead to waterlogging and salinity due to capillary rise from high water tables. The Irrigation Department of the North-West Frontier Province recognizes the danger. Currently, farmers in the completed part of the Chasma Right Bank Canal (Stage 1) receive more canal supplies than designed and what they will receive when all three stages of the project are in operation. The analysis indicated that a harmful rise of the water table is likely to occur before the two later stages are finished. In the meantime, farmers are becoming accustomed to receiving the higher-than-designed supplies of canal water which they use for growing rice on far more land than was planned. The solution to this problem would be to limit water supplies to the farmers in order to reduce the area under rice cultivation. Since, for hydraulic reasons, the main canal needs to flow at near full supply level to reduce siltation, it is imperative to ensure that more canal water flows back to the river rather than being applied to the fields. Even under the best water management, the natural drainage in the Chasma command area is unlikely to be adequate to handle the required leaching volume and the losses that will occur if the current practices continue. Consequently, if the corrective measures suggested here are not taken soon, subsurface drainage will have to be provided within the next few years to sustain the agricultural productivity of the land.

The situation at the sites located in the Punjab is completely different, but equally unsustainable. Here overexploitation of groundwater of marginal quality leads to lowering of the water tables combined with increasing salinity of the soil profile. For irrigation and agronomic practices to become sustainable during kharif at the Gugera site, the water balance should be reduced from the current 200 percent to 100 percent—groundwater pumping should equal groundwater recharge—by reducing the cropping intensity to 45 percent. However, current practices during rabi at the Gugera site are sustainable as the change in electrical conductivity of the soil water is negative and the extraction from groundwater is in balance with recharge. Overall, the current annual cropping intensity of 155 percent is not sustainable and needs to be reduced to around 130 percent.

The analysis of the water balance of the Fordwah/Eastern Sadiqia site shows similar results—the annual cropping intensity needs to be reduced from the present 130 percent to 93 percent to be sustainable. Alternatively, improved salt and water balances could be maintained by reducing the water supply per unit of land by cultivating larger areas and by using different cropping patterns, or by introducing crops that demand less water.

This study indicates that the current irrigation and agronomic practices at all three sites should not be continued for much longer. These hazards are well known by the irrigation agencies but rarely have they been provided with such quantitative information. Clearly, there is an urgent need to undertake more widespread analyses as remedial action must be taken soon to ensure that irrigation and agronomic practices can be sustained.

Management Turnover in Colombia

In 1975, farmers in two irrigation districts—Coello and Saldaña—in the Tolima Valley, Colombia, petitioned the government for the right to take over management of the districts. They based their argument on the fact that, over the previous twenty years, they had already repaid their agreed 90 percent share of the cost of construction. Furthermore, they were dissatisfied with the cost and quality of irrigation management for which they had paid water fees to the government, and claimed they could manage the systems more cost-effectively. In 1976, the government agreed to the farmers' demands, expecting that turning over the management of the irrigation districts would save it money. This was the first instance of management turnover in Colombia.

IIMI conducted a study from 1993 to 1995 to assess the extent to which the turnover program had made an impact on the cost of irrigation to farmers and the government, the quality of water distribution, and the sustainability of irrigation. The study involved a review of the financial viability of the districts, the physical condition of irrigation structures, the efficiency and equity of water distribution, and the productivity of water. Group and individual interviews were held with farmers, district management staff, agency staff, and board members.

The irrigation system in the Coello-Saldaña districts became operational in 1953 (figure 3). Cotton became an important crop but rice became the main irrigated crop from the 1970s. Today, maize, sorghum, fruit, and vegetables are also cultivated. Initially, Coello and Saldaña were constructed and managed as a single distributary but were separated in 1976 after management was turned over to the water users' associations.

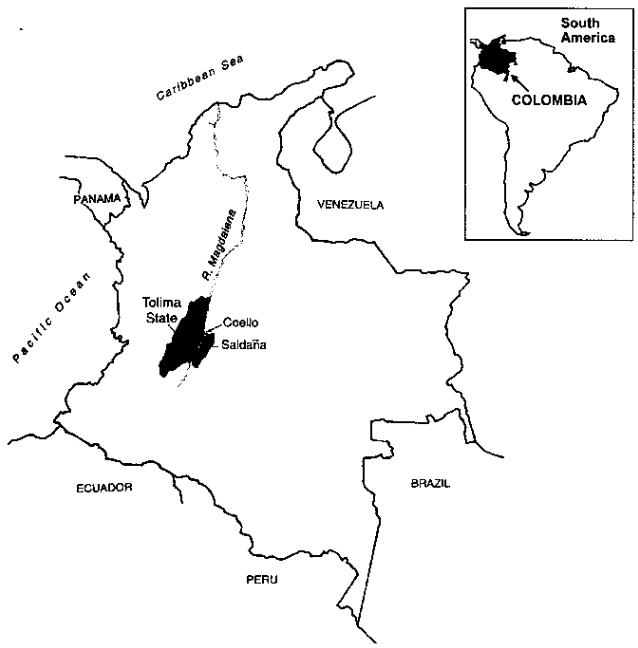
The Coello irrigation district is a river diversion system which, in 1993, served an irrigated area of 25,600 hectares, making it one of the largest schemes in the country. The Saldaña district, located south of Coello, also a river diversion scheme, irrigated 13,975 hectares.

Irrigation canals and natural drains in Coello and Saldaña were rehabilitated well before turnover. At the time of management turnover in 1976, the systems were considered by the government and farmers to be in good physical condition, so rehabilitation was not an issue in negotiations between them. However, the issue of who should be responsible for financing rehabilitation in the future has always been a matter of dispute. Farmers have argued that because the government had not turned over ownership of the infrastructure, it belonged to the nation and was the government's responsibility to maintain. Despite pressure from the government, farmers have persistently refused to repay the cost of rehabilitation in either system.

The turnover process

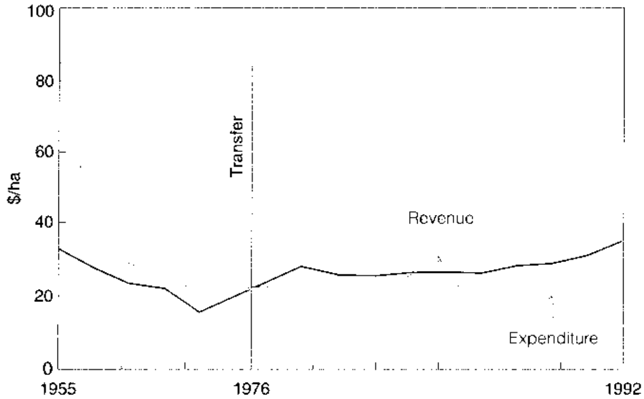
In 1975, the farmers, who had already formed associations, decided to formally request the government to transfer management responsibility for the two districts to the water users' associations. Negotiations for the transfer of the management were completed within a year. The issues resolved included the disposition of district staff, ownership status of scheme assets, and the future degree of involvement of the Institute for Hydrology, Meteorology and Land Development (HIMAT). It was agreed that most of the existing staff would be retained by the districts and the remainder transferred. The ownership of the irrigation structures would remain with the government, although some equipment and facilities were transferred to the farmers' associations. The government concluded that under existing laws it could not relinquish ownership of scheme assets, and HIMAT would retain a role of oversight for district management to ensure that the systems were properly maintained. In practice, HIMAT continued to give advice and consent for annual budgets, O&M work plans, setting water fee levels, and personnel changes. The farmers' associations obtained direct control over the O&M of the entire system, including the intakes.

Figure 3. Location of the Coello and Saldaña irrigation districts.



The transfer process invoked a legal rule in the country's constitution, referred to as the "delegation of administration," by which public goods (in this case, an irrigation district) could be turned over to a private corporate entity (a water users' association) for administration on behalf of the state. The users were then empowered to recruit staff and organize and take responsibility for O&M for the two systems, with the proviso that the users' association would be financially self-reliant. Government subsidies for O&M would be discontinued. However, labor laws prohibited firing of existing staff previously hired by the government. This created a labor relations conflict between the districts and the government until 1993 when Colombia enacted a new land development law intended to grant to farmers' associations full control over irrigation district management.

Figure 4. Revenue and expenditure per hectare, Coello district, 1955–92.



Changes in financial performance

Through turnover, farmers expected to improve management and reduce the cost of irrigation. It soon became apparent that although farmers had wanted HIMAT to play an advisory role, the government would not give farmers' associations complete control over their budgets, O&M plans and staff decisions. Consequently, the districts were unable to reduce staff and costs as much as they needed.

Prior to turnover, two kinds of water charges were levied—a flat area charge (based on farm area irrigated) and a volumetric charge (based on basic water requirements by crop type). The revenues from the area charge were used to guarantee the coverage of fixed costs such as personnel, while the volumetric fees were used more for variable costs such as operations. This system did not change after turnover.

Because the associations did not receive ownership of system assets and had not paid for previous rehabilitation costs, the farmers expected the government to pay for any future rehabilitation or replacement of structures. Consequently, after turnover, farmers did not raise a capital-replacement fund.

In taking over management of the irrigation districts, farmers hoped to enhance the cost efficiency and quality of O&M without sacrificing the agricultural productivity and financial and physical sustainability of the districts. The government's interest in the transfer was to reduce its subsidies to the irrigation sector through a national policy of management transfer. In Coello and Saldaña, the government discontinued its subsidies for O&M but continues to fully finance rehabilitation. If farmers defer maintenance, expecting the government to finance future rehabilitations, the government may not conserve as much money in the irrigation sector as it had planned.

The associations' irrigation policy which gave priority to balancing budgets, containing the cost of management, and achieving a more responsive irrigation service was only partially successful. During the initial stages of scheme development in Coello, expenditures exceeded revenues (figure 4). Between 1983 and 1992 revenues always exceeded expenditures, except in 1984.

Saldaña district was in a weaker financial position than Coello after

Figure 5. Revenue and expenditure per hectare, Saldaña district, 1953–92.

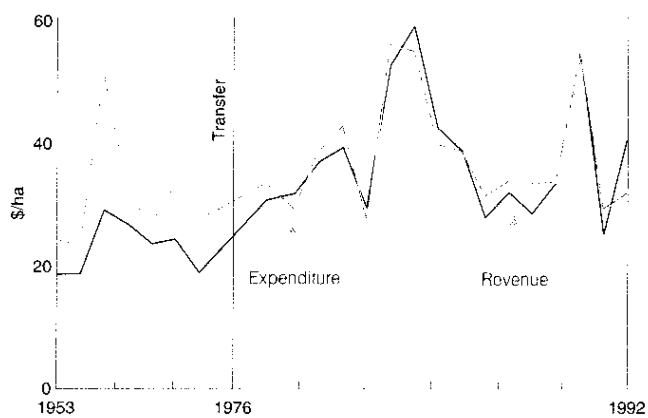
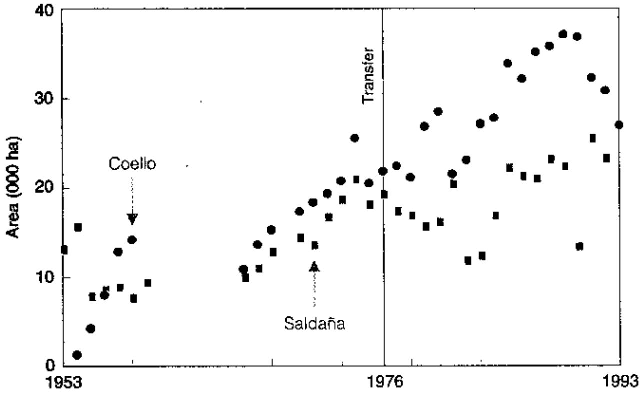


Figure 6. Gross annual irrigated area before and after transfer, Coello and Saldaña districts, 1953–93.



turnover, with expenditures exceeding revenues for six of the ten years between 1983 and 1992 (figure 5). However, the district gradually strengthened its position. Overall, both districts improved their financial positions after turnover, although from opposite directions—Coello reduced its surplus and enhanced efficiency and Saldaña diminished its pattern of deficits.

Organization and personnel

Following management transfer, the farmer association general assemblies for Coello and Saldaña districts elected boards of directors to supervise their districts. Directors were elected in a general assembly every two years. Each board was responsible for recruiting and selecting the general manager and participating in the selection or release of other district staff. Each board recruited a general manager who was an engineer and the districts became responsible for the day-to-day O&M of the systems. Over time, reductions in personnel allowed the management to streamline the organizational structure by combining sections and integrating functions.

One of the significant outcomes of turnover was the reduction of personnel. Before transfer, the districts employed 300 staff. By 1993, the total staff for both districts was down to 189, a 37 percent reduction. This reduction resulted in changes of service area from 62 hectares per district staff member in 1975 to 147 hectares per district staff member in 1993. Labor laws made it difficult for district managers to release dispensable government employees. Most reductions were in maintenance and technical support staff and occurred gradually, primarily through attrition and non-replacement. Nevertheless, district board members and agency officials reported that paperwork diminished and administration became more efficient after transfer, especially in irrigation scheduling, fee processing, and communications between users and district management.

Operational performance

The system of water allocation, made on the basis of area and crop type, remained the same after turnover. In theory, all users who planted the same crop type received a basic allotment, and they paid area and volumetric charges based on assumed deliveries relative to per-hectare targets by crop type. Irrigation was scheduled on the basis of preseason crop plans, modified during the season through water requests submitted by registered farmers, and district management prepared irrigation schedules based on the orders. Irrigation requests were approved to the extent that predicted water availability met the aggregate demand.

After turnover, the new district administrations introduced revised practices to improve irrigation efficiency and in particular, to allow continued expansion of irrigated area (figure 6). Expansion of area was made possible, in part, by policies which promoted delivery of less water per unit of land. Attention was paid to reducing staff where possible and revising cropping patterns to be consistent with the relative scarcity of water in the two systems. In Coello, where water supplies were insufficient for planting rice over the entire system, the association introduced a rice rotation and zoning plan which excluded sandy areas from rice production, restricted continuous cultivation of rice, and encouraged crop diversification. In Saldaña, where water was more abundant, the association introduced a continuous, staggered planting arrangement for rice allowing 2,000 hectares of rice to be planted every month, year-round. Not only did this improve water distribution but, according to farmers, it also improved profit margins by spreading rice marketing throughout the year.

There was no indication that the operational performance of the Coello or Saldaña systems changed significantly as a result of turnover. The total conveyance efficiencies—annual volume of water diverted at the headworks relative to the aggregate amount of water delivered to all tertiary canals—in Saldaña and Coello from 1982 to 1993, averaged 60 and 69 percent, respectively. The high sediment load in main canals was the apparent cause of these relatively low efficiencies.

Farmer associations became responsible for maintenance after turnover.

A simple effort was made to assess the equity of water distribution along tertiary canals in Saldaña by calculating the delivery performance ratio—the ratio between target and actual water discharges—at the outlets from the head to tail ends. The ratio exhibited a clear downward trend, ranging from 260 percent at the head to 75 percent at the tail, suggesting that distribution problems existed at the tertiary level. While the problems identified in operation and maintenance at the tertiary and distributary levels were not severe, the study indicated that improvements were necessary.

Physical sustainability

In both districts, 55 to 60 percent of total district income went toward maintenance of the irrigation network. This percentage did not change significantly after turnover because O&M budgets continued to be based on the previous year's budget and were reviewed and approved by the government. Managers of the districts expressed concern, however, that the farmers' strong emphasis on cost reduction was compromising the physical sustainability of the systems. To examine this issue, IIMI conducted a comprehensive survey of all structures and canal lengths in both systems in 1994. The survey classified canal sections as fully functional, partially functional, or dysfunctional. The review showed that in Coello, 98 percent of the total canal length was fully or partially functional while in Saldaña the corresponding value was 92 percent. Given that construction was completed in 1953 and only limited rehabilitation had been done in both districts during the late 1960s and early 1970s, and that management was transferred to the farmers' associations in 1976, this was a remarkable record.

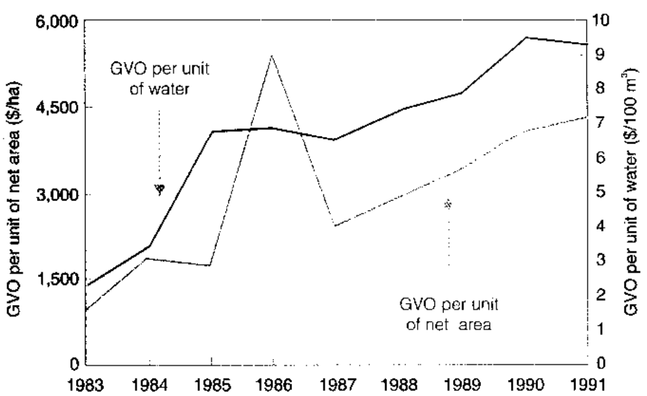
Agricultural productivity

The gradual expansion of irrigated area halted for about four years at the time of turnover, perhaps because of uncertainties and inefficiencies temporarily created by the change in management. But the expansion resumed after this period and only began leveling off early in the 1990s. The rate of expansion was higher in Coello where crop diversification occurred.

Area expansion was primarily a result of two factors. First, the tertiary network was extended and improved over time. Second, as farmers gained more experience with irrigation and their livelihoods improved, they expanded the area irrigated within their farms. Most of the change occurred when modern, fertilizer-responsive varieties were introduced in the 1960s and 1970s. By the 1990s, average rice yields were between 6.5 t/ha and 7.0 t/ha. Most of the increase in yields occurred before transfer, but high yield levels were sustained through to the early 1990s.

In Coello, the total cost of water relative to the cost of rice production dropped by over 4 percent during the 1950s largely due the cost of production. Under post-transfer management the total cost of irrigation remained essentially constant at around US$50/ha. The total gross value for irrigated crops on the other hand, rose fourfold, from US$944 in 1983 to US$4,300 per hectare in 1991 (figure 7). Coello district also achieved impressive gains in gross value of output (GVO) per unit of water, quadrupling in the period 1983 to 1991 (figure 7). These changes primarily reflected the rise in crop prices and the enhanced value per unit of water due to crop diversification. The cost of irrigation as a percentage of GVO was relatively small however, falling from 5.4 percent to 1.2 percent by 1991 (figure 8).

Figure 7. GVO in relation to net area and water use in Coello, 1983–91.

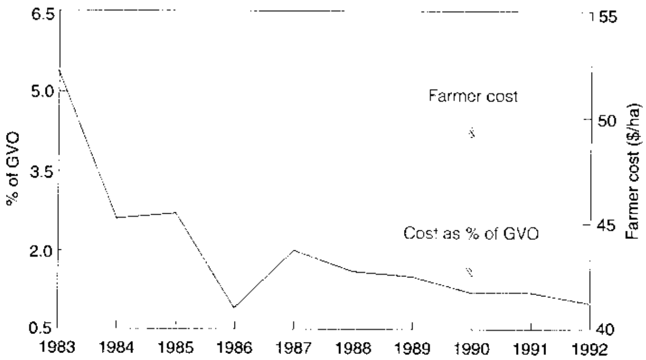


Stakeholder perspectives

The initiative for the turnover of management came from the water users. At the time of turnover, farmers were already financing most of the cost of O&M and expected to keep the irrigation fees from rising, and possibly, even reducing them. In 1976, farmers agreed that HIMAT should continue to provide oversight and advice to the user's associations but it soon became apparent that HIMAT's role after turnover went beyond oversight. Many farmers saw HIMAT as restricting their ability to further reduce staff and budgets so that many farmers perceived the transfer as being less than enough to give them full control.

During 1994, the study solicited the views of the stakeholders—farmers and, district and agency staff—on various aspects of the turnover of Coella and Saldaña. Most farmers saw turnover as having produced a more responsive and cost-efficient management. They favored a continuing limited role for the agency, primarily in providing technical advice and help with resolving disputes. The majority of farmers believed that the association should own the irrigation infrastructure. Although most farmers appeared satisfied with the performance

Figure 8. Irrigation cost as a percentage of GVO and cost of irrigation per hectare to farmers in Coello, 1983–91.



of O&M tasks, many believed that management performance, especially cost efficiency, could have improved had the users been granted full control over staff and budgets after turnover.

The professional staff in the districts was less sanguine about the results, expressing concern that cost-cutting measures compromised the quality of O&M. The agency was concerned about the implications of turnover on agency staff and budgets.

Overall impacts

The study found that turnover succeeded in achieving the government's main objective of discontinuing government financing for O&M. Since the government retained partial control over the irrigation districts after turnover however, staff levels declined slowly and the cost of irrigation to farmers changed little. The detailed inventory of irrigation infrastructure found that the vast majority of structures and canal lengths were in good functional condition. The districts were able to continue modest expansion of the irrigated area and sustain high levels of production after turnover, partially due to a policy to limit rice production and deliver lower volumes of water per hectare. Turnover also achieved the farmers' objective of preventing the cost of irrigation from increasing after turnover. Additionally, the gross economic value of production per hectare and per unit of water both grew dramatically.

Alternative Approaches to Cost Sharing for Water Service to Agriculture in Egypt

This study was designed to help the Egyptian government formulate a rational approach for sharing the costs of water services among the beneficiaries—agriculture and other users—and itself. The work combined and interpreted results from a number of earlier studies undertaken by IIMI for the United States Agency for International Development in Egypt during 1995. A key component of these studies was a review of cost-recovery policies in the water sector and an analysis of the impact of alternative approaches to water service charges on the agriculture sector.

Service charges are potentially important and useful because (1) recovering costs from beneficiaries of the service relieves the government of a financial burden and provides revenues to support operation and maintenance (O&M), (2) linking payment to the service provided should encourage efficiency in the provision of the service, and (3) they encourage efficiency in the use of resources provided.

In assessing the alternative approaches to cost sharing, each of these objectives was addressed: the financial objective, to recover from beneficiaries the cost of providing water-related services, and the two efficiency objectives, to encourage efficient, cost-effective provision of the water service and to encourage efficient use of the resource provided. This involved making

- a detailed review of the actual costs incurred in operating and maintaining the infrastructure for water delivery and disposal

- an assessment of the allocation of these costs among beneficiaries

- an analysis of the impact of alternative bases on the agriculture sector for imposing charges—flat-rate, volumetric, or crop-based

Cost-recovery practices

Charging users for water and water services is a sensitive issue in Egypt, as it is in many countries, involving political, historical, social, religious, and economic factors. Until the late 1980s, government revenues from agriculture were derived from implicit taxes on agricultural production: prices of farm products were low, marketing was controlled, cropping patterns were set to meet government priorities, and the government captured substantial profits from the sale of commodities (especially cotton) in world markets. These policies, combined with increasing domestic demands, resulted in a rapid deterioration in the agricultural trade balance. To restore farmers' incentives, the agriculture policy was radically reformed in 1986. Much closer correspondence between international and domestic prices for major crops was allowed, and controls on cropping patterns were, for the most part, eliminated. The effect of this policy change was dramatic. Yields and production of major crops rose sharply, and farm incomes rose by 25 percent in real terms. During this period of rapid adjustment, government revenues from the agriculture sector fell sharply and provided an opportunity to adjust other prices to more appropriate levels. Some subsidies for farm inputs were reduced but charges for water services (to agriculture or to other users) were not introduced.

Allocation of operation and management costs

Two common approaches for allocating O&M costs were considered, the use of the facilities method, and the separable costs, remaining benefits method (SCRB). The facilities method relies heavily on disaggregated data which were not available at the time of the study. Consequently, the SCRB method, which had been applied in 1993 by the Irrigation Support Project for Asia and the Near East (ISPAN), was chosen. The SCRB approach however, is normally applied in a planning context, where investments are yet to take place, and options exist to change the configuration of the investment and hence the groups, sectors, and areas to be benefited. The application of SCRB to a system that had been in place for many years introduced a number of difficulties. Accordingly, modifications were made to the model which allowed extensive exploration of a variety of underlying assumptions and sensitivity tests to differing levels of benefit in agriculture, different assumptions about New Lands development, and alternative estimates of benefits to other sectors. Representative results from the updated model are presented in table 4.

For the agriculture sector, the stability of these results was tested for sensitivity to the major variables—benefits to the

Table 4. Representive results from the updated ISPAN model.

Sector	Cost (US$)
Municipal and Industrial (per 000 m³)	
Canal delivery	3.63
Direct intake or groundwater	0.48
Industrial direct intake	0.69
Old Lands Agriculture	
Land basis (per ha/year	52
Volume basis (per 000 m³)	3.44
New Lands Agriculture	
Land basis (per ha/year)	53
Volume basis (per 000 m³)	3.34

agriculture sector, various scenarios of New Lands development, rates of growth in industrial production, and revised assumptions about population growth rates. The variation in the costs allocated to agriculture was in all cases marginal. A 15 percent change in estimated agricultural benefits, the most sensitive variable, produced only a 3 percent change in the computed service charge.

Impact of water service charges on agriculture

An analysis was undertaken using a model of Egypt's agriculture sector developed by the International Food Policy Research Institute (IFPRI), which was a modified, extended, and more complete version of the United Nations Development Programme's agro-economic model developed as part of the Water Master Plan. The analysis was designed to explore

- the actual relationship between farm incomes and service charges
- the impact of alternative charging methods on farm income and crop production
- the impact of volumetric charges on demand for water

and in each case, the charges were set so that total revenue remained equal to actual average O&M costs, estimated at US$52/ha annually.

Annual net farm income estimates based on the IFPRI model averaged about US$1,200/ha (that is, income to the farm enterprise, excluding the cost of family labor). This was quite consistent with other estimates. In 1994, the World Bank estimated that farm incomes ranged from US$1,200 to US$1,500 while others estimated that individual crop returns ranged from US$375/ha (flax) to US$1,700/ha (cotton), with most crops falling into the range of US$600 to US$1,000. With a cropping intensity of about 180 percent, net farm incomes would have ranged from about US$950 to US$2,000/ha annually.

For a net farm income of US$1,250/ha, full cost recovery of water services for irrigation would have reduced farm incomes by about 4.5 percent.

To determine the impact of alternative charging systems on production, the following options were analyzed:

- a fixed rate per hectare, irrespective of crop or water use
- crop-specific rates, charging higher rates for more water-intensive crops
- volumetric charges on the basis of actual water use

The first option was a simple undifferentiated annual tax of US$52/ha, and the resultant fall in farm income of 4.5 percent illustrated that a flat land tax had no significant impact on the choice of crops or technology.

The second option simulated a crop-water charge per hectare proportional to the calculated average water consumption. This option gave the farmer considerable incentive to fine-tune his cropping so the result was greater efficiency both from the farmer's perspective (farm income falling only 2.4 percent), and from the national perspective (water demand falling by 3.5 percent), while returns to water increased by 2.7 percent.

The third option imposed a volumetric charge and simulated the effect of measuring and charging for the quantity of water delivered. These results were virtually identical to those obtained through the second option.

The role of management

In Egypt water is moderately scarce. The model shows a positive but small marginal value product of US$0.02/m, compared with an average productivity of US$0.08/m. In future, significant reductions in supplies of water to agriculture can be anticipated as a result of transfers to competing demands, further development of new lands, and full utilization of agreed-upon upstream riparian rights. For the analysis, a 15 percent reduction in supply was hypothesized and the model was significantly revised to simulate the following scenarios:

1. current management, which would result in concentration of shortages at tail ends or otherwise disadvantaged locations

2. efficient management, which would share shortages equitably among all farmers

If shortages are not evenly distributed, farmers who have better access to water continue to seek maximum returns to land, and farmers who have worse access receive residual supplies and experience a more severe shortage, often exacerbated by unreliability. The second scenario presumes uniform distribution of shortages. Under these circumstances, farmers seek an efficient response to shortage by changing the cropping patterns to make the best use of the reduced water supply. To formulate this issue within the model, an arbitrary decision had to be taken about the division of the area into those with "better" and "worse" access to water. As a first approximation, the advantaged and disadvantaged areas were assumed to be equal. The results illustrated that from the national perspective, a water shortage of 15 percent, if inefficiently managed (concentrated among tail-end farmers), would result in a 7.1 percent fall in agricultural production, but an efficiently managed shortage (evenly distributed among all farmers) would limit the fall in agricultural production to 4 percent.

The role of water pricing

Finally, the usefulness of volumetric water pricing as a mechanism to promote more efficient water use was explored. In the previous section, the impact of a reduction in supplies of 15 percent was assessed in relation to two levels of management, each of which was essentially a rationing procedure. Here, the approach was to use pricing as a means of reducing demand. The analysis showed that the volumetric charge required to induce a 15 percent fall in demand would equal US$300/ha, or about 25 percent of the net farm income.

Future considerations

The results of the analyses show that any of the service-charge schemes would meet the criterion of recovering the full financial cost of the service. However, the level of service charges required to meet the financial objective was so low (6 percent of farm costs and 4.5 percent of farm income) that their impact on cropping decisions by farmers would be minimal for any system of water charges.

The results of the study using the modified IFPRI model clearly illustrate that even volumetric charges are unlikely to produce significant efficiency gains within the politically feasible range of charges. It was interesting to note the benefits of the volumetric supply in relation to possible costs. The prevailing delivery system, for the most part, provided farmers with the water they needed—unmeasured and undifferentiated—at the farm level. Consequently, any form of rationing or volumetric delivery will require quite a different infrastructure to allow the necessary measurement of individual supplies and the differentiation of deliveries between farmers.

Currently, the system operates as a demand system with enough water to meet the vast majority of needs. If this is to continue (that is, if water supply to existing agriculture is not going to be significantly cut by direct withdrawals for New Lands, by increasing demands for water-intensive crops, and by effective reductions in available water through high rates of pollution), it is doubtful whether formal water allocation would be required—the system can simply continue to be run as a demand system. If serious shortages occur however, far clearer legal definitions of water rights and water services will be required. Thus, the driving logic for establishing service definitions will be future water demands and the consequent water balance rather than cost-recovery considerations.

Conclusions

- The average annual cost of providing water services to agriculture was about US$52/ha—about 4.5 percent of net farm income.
- The above cost was hardly affected by likely variations in underlying assumptions governing the allocation of costs among sectors.
- Under prevailing conditions of supply, volumetric charges for water were only marginally more successful in encouraging efficient water use than crop-based charges.
- Volumetric charges were an unrealistic means of encouraging significant reductions in demand because very high charges were required to have a significant impact.

Satellite Remote Sensing for Improving Irrigation System Performance in India

The Bhadra Project, located on the Bhadra River in the State of Karnataka in India, is divided into the Bhadravati, Malabennur and Dvangere divisions. The project comprises a dam with a gross storage capacity of 2,025 Mm^3, a Left Bank Canal with a command area of 8,290 hectares, and a Right Bank Canal serving 92,360 hectares (figure 9). The different components of the Bhadra Project were constructed between 1948 and 1966 and designed to irrigate semidry crops that were to occupy more than 60 percent of the command area, with an overall annual cropping intensity of 200 percent. As agricultural development of the command areas grew, rice cultivation began to dominate, ultimately reaching 90 percent of the irrigated land in the Left Bank and around 50 percent of the irrigated land on the Right Bank. The heavy demand for water for rice cultivation led to inequitable use of the irrigation water supplies. The more powerful farmers in the area intervened and modified the water management plan provoking considerable dissatisfaction among tail-end farmers, and leading to rapid deterioration of the irrigation system.

In 1988, the National Water Management Project (NWMP) designed a scheme to restore the physical structure of the system and develop and implement an appropriate water distribution policy aimed at improving the performance of the irrigation system. Following improvements to the project, the Government of India and the World Bank requested IIMI to evaluate the performance of these projects. As part of the study, IIMI coordinated research conducted under the intellectual leadership of the National Remote Sensing Agency (NRSA) of India, to evaluate Satellite Remote Sensing (SRS) techniques as an operational tool for monitoring and evaluating irrigation projects. This was the first attempt to use satellite remote sensing techniques to obtain primary data on agricultural productivity under disaggregated conditions in India.

Satellite remote sensing technology in India

At the time the study was carried out, six satellites—the Indian Remote Sensing Satellites 1B and P2, Landsat, the European Remote Sensing Satellite, and the National Oceanic and Atmospheric Administration 11 and 12—provided remotely sensed data over India. The data were received at the Indian Earth Station at Shadnagar, about 60 km from Hyderabad, and processed at the National Remote Sensing Agency facilities at Hyderabad. The combined revisit period was approximately nine days. Estimated costs of using satellite remote sensing techniques for crop evaluation, including data acquisition and interpretation, showed a minimum of two US cents per hectare for command areas larger than one million hectares, and a maximum of thirty US cents per hectare for command areas smaller than 10,000 hectares. The cost for monitoring waterlogging and salinity was less than one US cent per hectare for large commands, and ten US cents per hectare for small commands.

Figure 9. Location of the Bhadra Project command area.

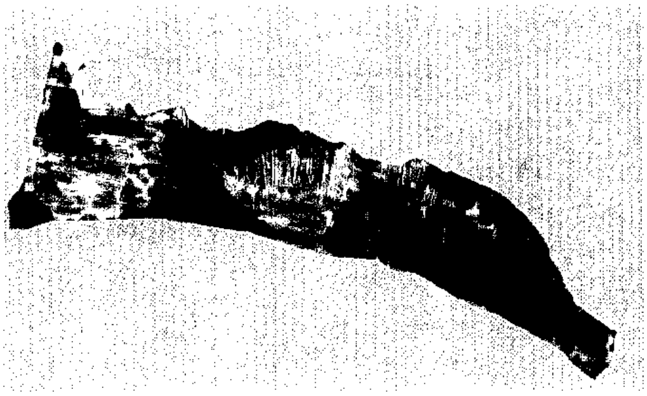
Crop classifications

Satellite remote sensing techniques were used to collect and analyze data from 1986 onwards on the cropping patterns and major crop conditions at disaggregated distributary- and canal-reaches for the rabi (winter) season in the Bhadra Project. Sample sites were selected so that nearby landmarks could be identified on the satellite images—suggesting that in future studies, it would be prudent to use Global Position System receivers to accurately identify locations of ground truthing data.

Beginning with the 1986–87 rabi season, information on the cropping pattern was generated by digitally analyzing standardized two-day satellite data. In the early stages of the study, the primary data on cropping pattern—rice/non-rice—were generated by visual interpretation of the images. Ground truthing was required to distinguish the different crop types and stages of development. In the end, to maintain acceptable levels of accuracy at the distributary level within the spatial resolution of Indian Remote Sensing Satellite and Linear Imaging Self-Scanning (LISS-I) sensor data, the final classification of crops distinguished only rice from non-rice crop groups. A more comprehensive classification into rice, sugarcane, semidry crops, and garden crops, even at the distributary level, is feasible if LISS-II sensor data are used, although accurate and detailed classification is also possible with LISS-I if the command area is taken as a whole.

On the other hand, the multivariate classification used in the Bhadra study uniquely classified different crop categories in multidimensional spectral space. Similar spectral signatures, particularly within cereals and between crops with geometric similarities, posed problems. Nevertheless, the post-classification validation check through field visits to more than 300 randomly selected points found the results to be 90 to 95 percent accurate. Distribution-level statistics were extracted by digitally overlaying the base map of the command area on geometrically rectified crop classification maps such as illustrated in figure 10.

Figure 10. Satellite image overlaid with cadastral details in Bhadra command.



Using SRS to determine and increase rice yields

The most commonly used indicator of rice crop condition is the normalized difference vegetation index (NDVI). In the 1992–93 rabi season, the rice yields at the crop-cutting experiment plots were compared with the corresponding normalized difference vegetation index from satellite data. The correlation coefficient was statistically significant as early as the panicle initiation stage, and highest when the crop was at the heading stage. Beyond the heading stage, the correlation coefficient decreased significantly. Since rice is transplanted over a period of days, single-day satellite data do not give a uniform growth stage of the crop. To overcome this obstacle, the maximum NDVI value was picked from multi-day satellite data at the heading stage. Analysis of the data resulted in the construction of a rice yield model, validated through farmer surveys and the crop-cutting experiment data of the 1993–94 rabi season.

Spatial information on the transplantation time for rice across the command area was mapped and the seasonal vegetation index profile of every pixel of the rice crop was analyzed to identify the stage of peak-greenness. This information was used to calculate the transplantation time and generate information on how to stagger rice transplantation. Such data were particularly useful in assessing the compatibility between canal delivery schedules and the rice crop calendar at the distributary level.

Besides spatial information, figures on seasonal rice development profiles at distributary and canal-division levels were generated for the 1993–94 rabi season. Analysis of these figures showed that Wide Field Sensor data effectively captured the time profile of rice development and rice condition throughout the season, even at the distributary levels.

System performance evaluation

Primary data on agricultural productivity—cropping pattern and rice yield—were generated at distributary and reach levels from satellite data from 1986–87 to 1993–94 rabi seasons and evaluated against the NWMP implementation (table 5).

Analysis of the results showed that irrigation intensity increased in every sector of the command area and although rice was to be precluded and semidry crops encouraged during rabi under the NWMP, irrigation intensity actually increased from 76 percent to 91 percent, the area under rice cultivation from 56 to 69 percent, and rice yield from 3,786 kg/ha to 4,871 kg/ha.

Equity between head- and tail-reach areas of long distributaries was evaluated in terms of the differences between rice yields and shortfalls in irrigation intensities—known as 'gap' utilization. Figure 11 shows that the gap in the tail-reach areas is significant when compared to 100 percent irrigation in the head-reach areas, particularly in the upper tail-reach areas.

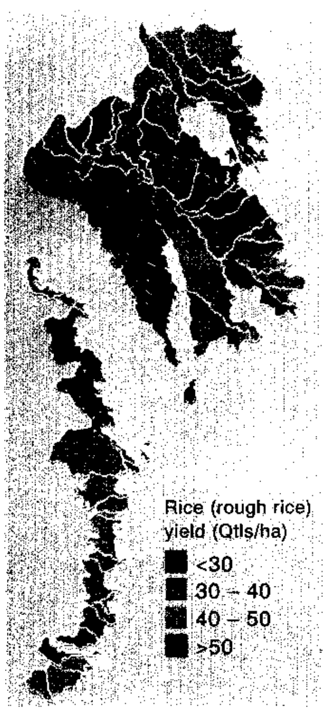
Table 5. Bhadra System performance under the NWMP.

Parameters	Rabi season 1986–87	1989–90	1992–93	1993–94
Irrigated crop area (ha)	73,529	67,366	88,424	84,412
Percentage of rice area	56	51	69	69
Average rice (rough rice) yield (quintals/ha)	37.86	53.99	46.85	48.71
Depth of water application (m/ha)	1.059	1.040	0.799	0.859
Area irrigated per unit volume of water (ha/m³)	94.44	96.12	125.21	116.37
Rice (rough rice) output per unit of land (tonnes/ha)	3.786	5.399	4.685	4.871
Rice (rough rice) output per unit volume of water (kg/m³)	0.282	0.396	0.495	0.478

Until the application of remote sensing techniques, crop yields were available only at the distributary level. When required, crop yield estimates were calculated from sample farmer surveys of selected distributaries. Now, for the first time, satellite data have provided objective rice yield information, even at reach levels within the distributary, allowing improved system performance evaluations. A comparison between figures 11 and 12 for example, indicates no strong correlation between irrigation intensity and yield intensity—yield intensities in some of the distributaries with 100 percent irrigation are smaller than those in other distributaries with lower irrigation intensities. This may be due to over-irrigation and waterlogging at the heads of the system.

Figure 11. Gap in irrigation utilization during rabi 1993–94.

Figure 12. Spatial variability in rice yield during rabi 1993–94.



Yield estimates could be extended even to non-rice crops and, if mapped accurately, system performance studies can be made on total agricultural production. Other performance indicators, such as depth of water application and rice production per unit of water, can be derived from the satellite data in conjunction with ground reported rainfall data and canal delivery data.

Under the NWMP, the performance of the Bhadra Project was shown to have made significant improvement in area irrigated, agricultural productivity, and equity of distribution. Only a few pockets of inequity remain to be corrected by the management.

Inclusion of geographic information systems for system performance evaluations

To help the system performance evaluation and diagnostic analysis, a geographic information system (GIS) using PAMAP software was developed. Digitized base maps provided the geographical framework, and relevant ground and satellite data were incorporated into PAMAP. In this study for instance, temporal and spatial data of agricultural productivity from each distributary were analyzed this way resulting in the production of figures 11 and 12. The GIS approach was also applied in the diagnostic analysis of three distributaries selected on system performance criteria from the Malebennur Canal Division.

These studies illustrated that linking GIS with the irrigation information system will facilitate the effective and efficient management of canal water delivery and scheduling, increase awareness of crop water requirements, and help analyze hydrometrological data and carry out operational plans.

The future of remote sensing in agricultural performance

The Bhadra study clearly demonstrated the potential and cost-effectiveness of using satellite remote sensing techniques for routine monitoring and performance evaluation of large-scale irrigation systems (see box). Integration of geographical information systems further enhanced the performance evaluation and diagnostic analysis capabilities of the approach.

Beyond the use of remote sensing techniques as an operation tool, they were shown to have value in project formulation and in identifying areas that need corrective management strategies. IIMI and the National Remote Sensing Agency are now undertaking further studies to explore the possibility of introducing these techniques as regular operational tools in the management of irrigation water.

Accomplishments

- Near real-time monitoring in the 1992–93 and 1993–94 rabi seasons provided primary data on the cropping pattern to project authorities before the end of the rabi season. These data helped the Irrigation Department authorities to identify problem distributaries in these two rabi seasons.
- An improved design for crop-cutting experiments based on satellite-derived data on crop area and crop condition was developed and implemented by the Agriculture Department during the 1994–95 rabi season.
- Analyses of multi-day satellite data of the rabi season helped identify spatial variability during the rice transplantation period throughout the command area.
- A geographic information system (GIS) was successfully developed by NRSA at two levels of the command area to evaluate system performance, and to diagnose and analyze problem distributaries.
- Cadastral maps of distributaries were digitized and successfully integrated with satellite data. If high resolution satellite data are used, NRSA believes that the collection of primary data even at the village level is feasible.
- Further research to overcome identified limitations should be guided toward improved crop classification algorithms, yield prediction models, vegetation indices, and satellite data normalization procedures.

Gender Analysis of an Irrigation Program in Bangladesh

Almost everywhere women's contributions to agriculture and irrigation are more important than generally assumed. A growing body of literature on women in development is serving to highlight the variability of the roles of men and women in farming and in the household. The failure to recognize the importance of women in agricultural activities and the gender relations that underlie and determine men's and women's roles have, in many instances, led to a worsening of the position of women.

A GKF group member irrigating her plots by opening and closing bunds.

Although recognition and awareness of the importance of gender relations for planning, designing and managing irrigation are growing, there are still few documented examples of irrigation approaches which make a conscious effort to incorporate gender issues. In this respect, the activities of the Grameen Krishi Foundation (GKF) in Bangladesh are particularly noteworthy. Founded in 1991 with the primary objective of profitably managing the deep tube wells that had been taken over from public agencies, the foundation has a remarkably explicit focus on women.

Lending to the rural poor and supporting income-generating activities are the primary activities of the Grameen Bank. The bank has gradually diversified its activities—primarily because of the government's eagerness to dispose of poorly performing development projects—and has set up enterprises based on fish and shrimp farming, cold storage facilities, as well as irrigated agriculture.

Irrigation was one of the most significant activities of the bank with over US$7 million invested in irrigation projects. To handle these activities a separate institution, the Grameen Krishi (Agricultural) Foundation, was created in 1991. In 1994, the foundation invited IIMI to help with the assessment of the impact of its irrigation program on the position of poor rural women, and to explore ways of increasing the benefits of irrigation to these women.

Aims

Irrigation and access to irrigation were considered to have provided important opportunities for improving the lives and empowerment of rural women. The study was initiated to assess if this was true—how had men and women belonging to different socioeconomic categories of households contributed to, and benefited from, irrigation, and had there been opportunities to better accommodate the irrigation-related needs of female farmers participating in irrigation?

The study was centered on a number of villages in the districts of Dinajpur, Kaharol, Kurigram, Kurigram Sadar, Dinajpur, Rajerhat Rangpur, and Thakurgaon. The work focused on the foundation's existing female group members and on women of households who have been involved in irrigated agriculture since the introduction of deep tube wells.

Individual interviews were held with thirty women farmers using a questionnaire designed to provide information on socioeconomics, division of labor in household crop production, participation in irrigation, water management, impacts of irrigation, and on other topics such as loan utilization.

Concepts and tools

The Feldstein and Poats framework on gender analysis in agriculture was applied. This framework described the distribution of activities, resources and benefits among household members and presented three sets of questions:

- Analysis of activities—who does what, when and where?
- Analysis of resources—who has access to or control over resources for production?
- Analysis of benefits and incentives—who benefits from each enterprise?

The framework was used to provide an overall picture of the gender-based organization of activities and to identify problems and opportunities for improving the situation of women in irrigation. The information generated by the framework was interpreted and analyzed in conjunction with other documented information on gender relations in rural Bangladesh.

Intra-household organization of irrigated rice production

The degree of involvement of male and female household members in irrigated agriculture and irrigation management appeared to be related to the size of landownership. In the poor or marginal farmer households (0.0041–0.2024 ha) most agricultural activities were found to be carried out by the family members themselves. In rice production specifically, more female family labor was used in the associated activities than male labor. In the absence of adult male household members, female-headed households engaged hired laborers, mostly men, for labor-intensive activities such as land preparation and harvesting.

In middle-class households (0.2024–1.2141 ha) family labor was divided almost equally between males and females. Finances permitting, these households preferred to use hired labor-

A GKF group member irrigating her vegetable garden with water from a hand tube well, using a 'golchi.'

ers rather than family labor. In particular, female-headed households preferred to use female laborers as it was easier to make direct contact with them and it was more socially acceptable for women to work alongside other women. Interestingly, female household heads paid female laborers the same wages as they paid to male laborers.

Apart from the traditional crop-processing tasks, greater use of female family labor was being made for making seedbeds, uprooting seedlings, transplanting, fertilizing, weeding and harvesting, all traditionally male activities. The involvement of women in irrigation tasks was striking. Between 40 to 50 percent of field irrigation and on-farm water management was performed by women, nearly equaling the contributions made by male family labor. Women often supervised the water delivery and distributed the irrigation water by opening and closing the bunds between plots. Notably, night irrigation was always supervised by men.

Religion had a significant influence on the intra-household organization of production. In Muslim male-headed families, women contributed 31 percent of the total labor while in Hindu male-headed families, women contributed 54 percent of all labor in rice production—Hindu women face fewer cultural restrictions when working outside the immediate homestead than Muslim women.

Shifting the position of women

The strictly enforced traditional rules preventing women from engaging in field-based stages of rice production were beginning to show signs of relaxation. Most women interviewed confirmed that their participation in agricultural activities had increased considerably over the previous five to ten years. Some could clearly recall the time when they only worked in the homestead, while today they had assumed many tasks beyond their traditional homestead. While women increasingly performed the tasks traditionally reserved for males, they remained totally responsible for the traditional female tasks thereby increasing their total work load.

Many women experienced their increased participation in rice production as a loss of social status and faced harsh social disapproval when working in the fields. To minimize these negative associations, women attempted to define their new roles in culturally acceptable ways. One Muslim widow in Rangpur, Bacha Mai, recalls: *I became a widow twenty-one years ago, and was lucky to inherit some land from my late husband. I had five young children at that time, whom I had to feed. My only choice was to cultivate my land to produce food for the family. People in the village made very rude remarks. They said: "she is a tribal," or "if she prays, God will not accept her prayer," and "she is the husband of a man" and other similar things. I continued with my struggle. Nowadays my life is easier as my son and daughter-in-law live in my house and help with all the work. I am now a professional farmer, doing all men's work. I am no longer interested in household work.*

Her response reflects the opinions of many of the interviewed women—they were proud of their achievements and agricultural knowledge.

Income sources

Women-headed households deriving their main incomes from agriculture were shown to be a vulnerable group. Access to inputs such as land, credit, seed and fertilizer were limited which, in turn, reduced agricultural outputs and family incomes. However, the introduction of the irrigation tube wells made it possible to grow crops all year-round and today, most farm households which have access to irrigation water cultivate two rice crops a year instead of a single rain-fed crop. Incomes derived from crop production resulted in an increase in income for 78 percent of the marginal farmer households, and for 100 percent of the middle farmer households.

Of the women belonging to landless and marginal farmer households, 67 percent reported a higher income through increased wage labor opportunities pointing out that payments were now made in cash rather than in kind, as was done in the past. For males of middle farmer households, the introduction of irrigated agriculture had significantly increased the scope to earn off-farm income. Those who had opportunities to earn income from businesses associated with rice or irrigation equipment comprised 82 percent.

Increases in income from animal production were reported in both marginal and middle households since revenues from improved crop production were invested in livestock. Caring for livestock, a predominantly female task, had become easier and women were often able to exert control over the income from the sale of milk, calves, and cow dung the latter being also used as manure and fuel.

The study showed that women were the main managers of household incomes although men had more power in deciding expenditure. The increased significance of women's contributions to household income did, nevertheless, allow them a greater say in how the money was to be used. Many women attached high priority to the education of their daughters.

Gender relations and irrigated agriculture

With the introduction of irrigation, and in spite of the predominant gender ideology in Bangladesh which discourages women from working in field-based stages of agriculture, poor rural women have increasingly assumed field-related and irrigation tasks. The highest involvement has been by female heads of households, women in landless and marginal farmer households, and by women from Hindu households.

The analysis highlighted that the impacts of irrigation development were different for different socioeconomic categories. Households with reliable access to land and agricultural inputs benefited more directly from access to new irrigation technologies and irrigation water. The most important direct benefits for land-poor households were the increased opportunities for wage employment and the sharp increase in female wage labor opportunities.

Women repeatedly referred to the change in traditional purdah norms—many appeared happy with the increased freedom of mobility they enjoyed even though it initially implied a loss of social status. Most women interviewed in this study were of the opinion that the loss of social status was compensated for by an increase in household income. Women who had earned an additional income and managed to control its use felt proud of themselves and enjoyed their new status of income-earner or provider.

Grameen Krishi Foundation's gender strategy

As a partial consequence of the outcomes of the study, the foundation progressively realized the full extent to which women had a high involvement in farming. Given adequate support for farming activities, women were shown to be able to significantly increase their contributions to household incomes when compared to returns to labor in traditional female activities. Similarly, it was demonstrated that it was often difficult for women to fully enjoy the benefits of access to irrigation because their access to other resources (land, credit, seeds and fertilizer) and services (technical information and marketing) was constrained. This recognition prompted, in 1992, a shift in the foundation's gender strategy from the development of specific activities for women to mainstreaming, aiming at more directly involving female farmers in the foundation's core irrigation activities.

Consequently, the foundation made the decision to make irrigation services directly available to individuals or groups of women. According to the need, various services are provided which can involve access to deep or shallow tube wells, irrigation water, or to irrigation technology. On behalf of the women, foundation staff can negotiate with landlords to secure land lease arrangements and provide seeds, fertilizer, agricultural credit, technical training and marketing services.

The documentation process of the early projects has illustrated that the foundation's mainstreaming strategy is gradually showing signs of success and, from 1992, female involvement in the foundation's irrigation-related activities has increased dramatically.

The study shows that women, in spite of some difficulties, were highly motivated and well capable of managing irrigation equipment and irrigated crop production. Seasonal net income from irrigation ranged from US$25 to US$125 per season per woman—significantly higher than the US$12.50 they would have earned as wage laborers. Many women had plans to expand the scope of their involvement in irrigation to further increase their earnings.

The increased income-generating capacity and larger contributions to household income strengthened the self-confidence of women and reduced their dependence on male intermediaries. To overcome the loss of social status because of their higher involvement in field-related tasks, women organized themselves into groups.

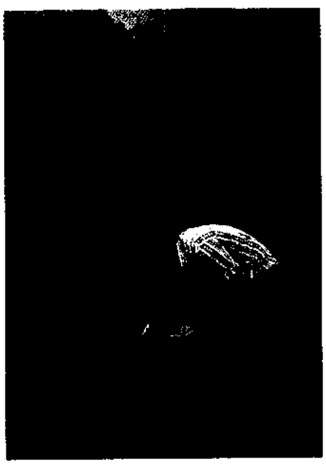
There was general concern that women did not have full control over the income they earned but the study suggested that control over household income increased as their contributions increased. The foundation could consider providing more direct marketing assistance to women to enable them to secure even greater control over their earnings. This would permit them to receive cash returns directly thereby avoiding dependency on their husbands, or on other male relatives, to market their produce. The provision of basic education to women would also grant them greater control over their incomes and loans, further alleviating their dependency on people who can read and write.

Lack of secure and long-term access to land is still a prime constraint for many poor women today. Although the Grameen Krishi Foundation has successfully arranged seasonal leases of land for women in a few instances, longer-term access to land remains a crucial factor if women are to fully benefit from improved access to irrigation services in the future.

Environmental Management for Disease Vector Control in Sri Lanka

Japanese encephalitis and malaria are perilous human diseases carried by mosquitoes. Although mosquitoes breed in irrigated lands, not enough is known about how the management of the water used for irrigation influences the life cycle of these insect vectors. But it is known that the productivity of farmer households can be significantly affected by these diseases. In 1994, IIMI set up the first of a series of projects in Sri Lanka to assess the impact of small-scale irrigation on the transmission of these diseases and to identify the direct and indirect costs of these diseases on farmer households.

Sampling the vector larvae.



The village of Mahameegaswewa, located in the dry zone of Sri Lanka, was chosen for the study as it had one of the highest incidences of malaria reported in the country. The village covered an area of 65 ha which included 60 homesteads, a number of small reservoirs or tanks, rice fields and *chenas* (slash-and-burn cultivated areas). A river, the Yan Oya, forms the western and southwestern boundaries of the village. For approximately 20 kilometers the Yan Oya is used as a natural feeder canal for conveying water from the Mahaweli irrigation system down, through a series of three small tanks, to the Huruluwewa tank. Earlier IIMI studies had shown that malaria was a considerable economic burden on the farmer households in this area—farmers incurred an average expenditure of US$3.00 on the costs of medical assistance and drugs to combat each episode of malaria, and lost five working days, on average, per episode. In any single year, farmers averaged four malaria episodes, incurring total losses of roughly 10 percent of the net household income per annum.

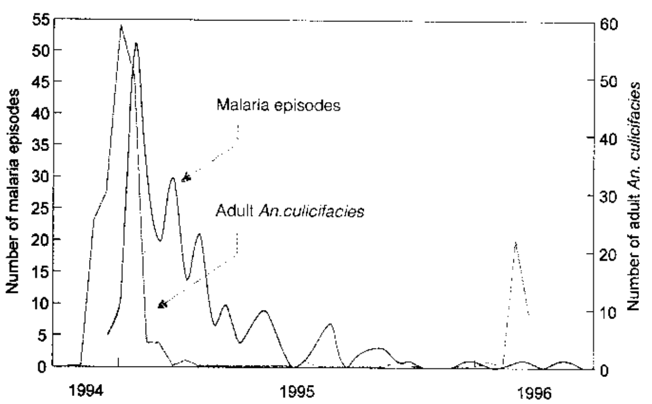
Sampling the vectors

Adult mosquitoes were collected from inside and outside of farmer households for three days every two weeks over the two-year period of the first phase of the study. Populations of mosquito larvae were taken from all habitat types in the study area on a fortnightly basis. The relative importance of different breeding habitats was identified and quantified. Malaria incidence data were collected from all 300 inhabitants for the complete study period.

The culprit

The most important vector of malaria in Mahameegaswewa, as in other areas of Sri Lanka, was the mosquito Anopheles culicifacies. This vector was found to build up its population through a shifting pattern of breeding. Starting in the pools created in the riverbed of the Yan Oya during the dry season, the mosquitoes later moved to deposit eggs in pools freshly created in the tank beds and in the drainage area below the command area at the onset of the rains. The latter could only be exploited however, within the fairly narrow time span when the pre-monsoon rains resulted in the establishment of pools in the empty tanks and drainage areas. Such sites were usually eliminated four to six weeks after the commencement of the rains when the tanks started to fill up and the drainage areas were covered with water.

Figure 13. Malaria episodes and adult An. culicifacies abundance in Mahameegaswewa village, July 1994 to March 1996.



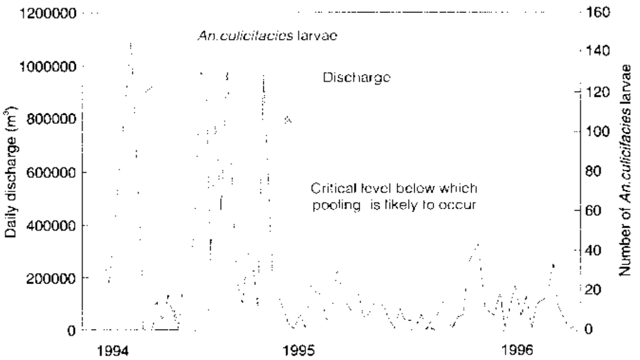
In an extended period in 1994, there were no water releases from the upstream tanks or rainfall, and the water level in the Yan Oya fell below a daily discharge of around 30,000 m^3. As a consequence, the population of Anopheles culicifacies grew significantly (figure 13). It was thought that without the long-term build-up of the mosquitoes in the pooling of the Yan Oya, the population of anopheles mosquitoes would be too small to fully exploit the short-lived habitats created in the village tank beds and the drainage areas. This theory was tested when, during a similar period in 1995, a limited amount of water was discharged from the upstream tanks preventing pooling in the riverbed. This action significantly reduced the mosquito population (figure 13) illustrating just how clearly mosquito breeding in the area was dependent upon the water flow dynamics of the Yan Oya.

The study illustrated equally and clearly the relationship between the numbers of Anopheles culicifacies and the incidence of malaria among the Mahameegaswewa villagers. Figure 14 shows how in 1994 the number of malaria episodes among the villagers peaked about one month after the peak in density of the mosquito larvae in the Yan Oya. Once the breeding cycle had been disrupted in the dry season of 1995 by the release of water, the population of mosquitoes was reduced to a minimum and the incidence of malaria was negligible.

The follow-on

The study on the village of Mahameegaswewa demonstrated how the incidence of malaria among the

Figure 14. Number of immature An.culicifacies *in Yan Oya and daily discharge, Mahameegaswewa village, August 1994 to March 1996.*



inhabitants was related to the management of water. IIMI is now extending the study to include seven more villages located in the same area. The study will assess the feasibility of implementing more sophisticated water management practices in the river to reduce the burden of malaria on village inhabitants and to provide adequate water for irrigated agriculture. If successful, the final solutions emerging from this work can be applied to other areas of the dry zone in Sri Lanka.

Finance and Administration 1995

In 1995, IIMI spent US$9.12 million of its income of 10.3 million as operating expenditures (see figure 15), 69% of which was devoted to research (see figure 16). Thus, the institute ended the year with a net operating income of US$1,178,954 of which the allocations were US$479,956 to capital purchases and the balance US$698,998 to the operating fund, respectively. In 1995, the institute used US$4.3 million in core unrestricted resources, US$3.05 million in core restricted support and US$3.0 million in complementary support. The institute's unencumbered cash assets at the end of 1995 were over US$3.5 million.

In 1995, the institute had thirty-nine internationally recruited staff. Some 138 national professional and management staff were engaged in IIMI's research, training, and information activities in headquarters and overseas units. IIMI's total staff numbered 397, more than half of them based outside Sri Lanka.

Figure 15. Operating expenditure, 1984–1995.

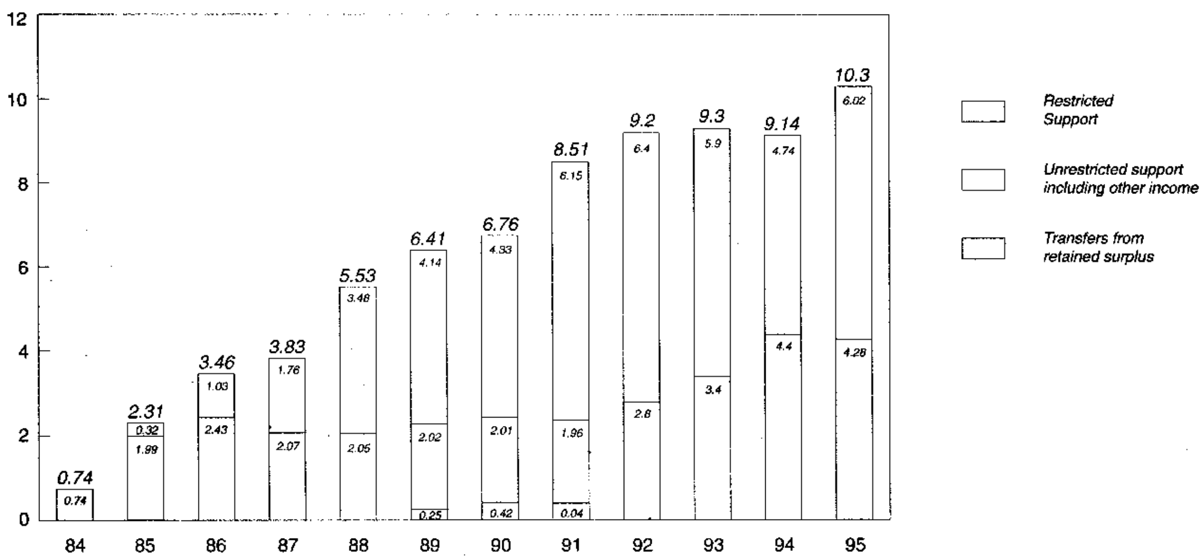


Figure 16. Research and governance expenditure, 1995.

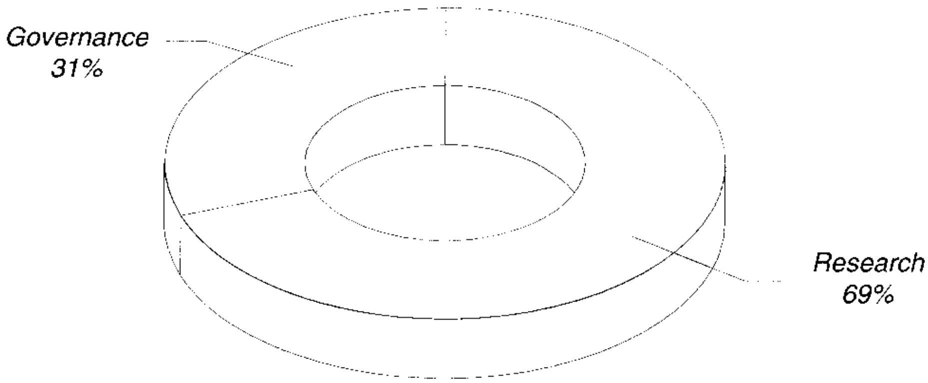


Table 6. Core Unrestricted, Core Restricted and Complementary 1995.

Donor	1995 Grant (US$)
Core Unrestricted	
Australia	111,930
CIDA	185,708
EU	420,822
Ford Foundation	350,000
France	145,757
Germany	348,238
Japan	254,140
Mexico	30,000
Spain	25,000
The Netherlands	541,860
USAID	200 ,000
World Bank	1,500,000
Subtotal (unrestricted)	4,113,455
Other Revenue	
Bank interest	123,136
Sundry income	39,141
Subtotal (other revenue)	162,277
Total Core (unrestricted resources)	4,275,732

Donor	Project	1995 Grant (US$)
Core Restricted		
ADB	Study on Privatization on Minor Irrigation: Bangladesh	170,479
ADB	NCP/PPTA Area Development Project	64,002
AFDB	Burkina Faso: Irrigation Management Development	168,285
AFDB	Niger: Irrigation Management Development	216,436
EU	National Irrigation Rehabilitation Project	272,783
DANIDA	Gender Issues	27,621
DANIDA	Health and Irrigation Study	16,902
DANIDA	Health and Irrigation Study II	43,073
FORD	Support for Bangladesh	40,251
FORD	Supplementary Support for Sudan	15,479
FORD	India Turnover Project	52,024
FORD	Water Rights Nepal	16,349
FORD	Irrigation Management for Latin America—Phase II	190,887
France	Support to Pakistan	11,064
Germany	Local Management	259,726
Germany	Privatization and Turnover	111,144
IDB	Andean Regional Project	112,878
India	Research Support	24,810
Japan	Performance	300,000
Japan	Environment	27,785
NORAD	Design of Environmental Management	7,781
The Netherlands	Gender Program	20,428
The Netherlands	Managing Irrigation for Environmentally Sustainable Agriculture	295,138
USAID	Sub-Saharan Africa	16,631
USAID	Shared Control of Natural Resources (SCOR)	411,938
	Subtotal	2,893,894

(Continued)

Table 6. Core Unrestricted, Core Restricted and Complementary 1995. *(Continued)*

Donor	Project	1995 Grant (US$)
Restricted		
Australia	Inter-Center Initiative on Water Resources Management	21,528
DANIDA	Inter-Center Initiative on Water Resources Management	49,985
France	Inter-Center Initiative on Water Resources Management	41,645
ROCKEFELLER	Inter-Center Initiative on Water Resources Management	25,000
USAID	Inter-Center Initiative on Water Resources Management	13,969
	Subtotal	152,127
	Subtotal core restricted	3,046,021
	Total core	7,321,753
Complementary		
ADB	Monitoring & Evaluation	34,857
ADB	Pehur Project	20,101
ADB	Sri Lanka Phase II	5,284
FAO	Fellowship	546
FORD	DG's Recruitment	89,310
FORD	DG's Sabbatical Leave	5,723
FORD	Irrigation Management of Irrigation Systems (Nigeria) Phase II	5,075
FORD	India Turnover Project	62,295
IDB	Andean Regional Project	34,720
ILO	Local Management, Nepal	3,291
Pakistan	Fordwah Eastern Sadiqia (South)	35,229
Sri Lanka	Kirindi Oya Irrigation and Settlement Project	22,587
The Netherlands	Managing Irrigation for Environmentally Sustainable Agriculture	389,361
USAID	Shared Control of Natural Resources (SCOR)	635,354
USAID	Strengthening Irrigation Management in Egypt	1,236,770
World Bank	LBOD Project	317,047
World Bank	National Water Management Project (NWMP)	83,698
	Subtotal complementary	2,981,248
	Total	10,303,001

Consolidated Statement of Financial Position at 31 December 1995

Assets	**1995 US$**	**1994 US$**
Current Assets		
Cash and cash equivalents	3,508,911	2,730,362
Accounts receivable:		
Donors	1,192,554	1,170,433
Employees	106,293	82,849
Others	174,664	184,941
Inventory	68,584	77,576
Prepaid expenses	272,384	257,243
Total current assets	5,323,390	4,503,404
Collateral for PRI loan	501,510	429,783
Fixed Assets		
Property, plant and equipment	4,683,939	4,486,758
Less: Accumulated depreciation	2,585,054	2,448,401
Total fixed assets - Net	2,098,885	2,038,357
Total Assets	**7,923,785**	**6,971,544**
Liabilities and Net Assets		
Current Liabilities		
Contribution received in advance	1,351,057	1,624,456
Other accounts payable	654,576	657,437
Accrued expenses	100,794	67,301
	2,106,427	2,349,194
Provision for Liabilities and Charges		
Severance/gratuity benefits	270,793	314,086
International staff repatriation	172,448	100,752
International and national staff unutilized leave provision	173,195	Nil
	616,436	414,838
Long-Term Debt		
PRI loan	442,052	586,484
Total liabilities	3,164,915	3,350,516
Net Assets		
Capital invested in fixed assets:		
Center-owned	1,292,383	1,099,693
In custody	254,796	238,823
Capital fund	1,172,342	942,161
Operating fund	1,537,839	910,568
Collateral for PRI loan	501,510	429,783
Total Net Assets	4,758,870	3,621,028
Total Liabilities and Net Assets	**7,923,785**	**6,971,544**

Source: 1995 Audited Accounts.

RESTRICTED PROJECTS 1995

Project	Donor	Pledged amount*	Duration (months)	Cumulative expenditure* to 31/12/1994	Expenditure* 1995
Core					
Study on Privatization of Minor Irrigation: Bangladesh To assist the government in reviewing the current status and impact of, and options and alternatives for, minor irrigation privatization, at the district and pump command-area levels.	Asian Development Bank	548,000	34	365,123	170,479
North Central Region Area Development Project: Sri Lanka To assist the government in the preparation of a comprehensive and sustainable development program to help alleviate poverty, generate employment, and optimize the use and conservation of natural resources in the North Central Province.	Asian Development Bank	80,000	8	Nil	64,002
Burkina Faso Program to strengthen the national capacity of national institutions to improve and sustain the performance of small-scale reservoir-based village irrigation schemes through collaborative research.	African Development Bank	1,112,673	60	695,830	168,285
Niger Evaluation of performance of Farmer-Managed Irrigation Systems on the Niger River Valley.	African Development Band	1,126,500	60	787,825	216,436
National Irrigation Rehabilitation Project (NIRP) To assist the Irrigation Department of Sri Lanka to identify research needs, support research programs which yield results of immediate interest to the irrigated agriculture sector, and to assist the Irrigation Department of Sri Lanka to establish an Irrigation Rehabilitation Management Unit (IRMU) which will contribute to the quality of planning and implementation of the Department's projects.	The European Union	ECU 843,840+ SL Rs 21,684,800	48	860,553	272,783

(Continued)

Restricted Projects 1995 *(Continued)*

Project	Donor	Pledged amount*	Duration (months)	Cumulative expenditure* to 31/12/1994	Expenditure* 1995
Gender Issues in Irrigation Management To increase the knowledge and understanding of gender issues in irrigation, especially the role of women in irrigated agriculture as well as its impact on women's lives; facilitate the incorporation of gender issues and analysis in ongoing IIMI activities with a view of developing a comprehensive statement on the linkages between gender issues and the performance of irrigated systems.	Danida	59,985	12	Nil	27,621
Health and Irrigation Project Support to continue work on IIMI's Health and Irrigation Project.	Danida	170,735	15	52,784	59,975
Bangladesh Partial support for an IIMI resident scientist to work on irrigation management in Bangladesh.	Ford Foundation Bangladesh	394,000	47	353,749	40,251
Sudan Supplementary support for an irrigation management program in the Sudan.	Ford Foundation New York	450,000	42	434,521	15,479
Monitoring and Evaluation of Irrigation Management Turnover in India Support for a study of transfer of management authority in Indian irrigation systems.	Ford Foundation New York	230,700	36	77,905	114,319
Nepal Support for documentation and analysis of customary and statutory water rights in Nepal.	Ford Foundation New York	200,000	30	174,582	16,349
Irrigation Management for Latin America—Phase II Support for initiating collaborative research and action to improve irrigation systems in Mexico and to plan similar programs throughout Latin America.	Ford Foundation New York	750,000	36	419,405	190,887
Support to Pakistan To reinforce the IIMI-CEMAGREF collaboration in Pakistan related to DSS, application of RS and GIS, analysis of economic impact of management changes, and to develop training activities for employees of collaborating institutes in Pakistan.	France	24,171	12	Nil	11,064

Restricted Projects 1995 *(Continued)*

Project	Donor	Pledged amount*	Duration (months)	Cumulative expenditure* to 31/12/1994	Expenditure* 1995
Program of Support Systems for Local Management in Irrigation To define the critical elements of the necessary support system required for sustainable local management of irrigation systems.	Germany	DM 1,651,115	36	95,036	259,726
Privatization and Self-management of Irrigation To support case studies; to conduct research development programs for turnover in selected countries where turnover is underway with a view to develop decision-support packages for governments that are considering transfer to local management; develop a center of information and facilitate exchange of information among countries engaged in the turnover process.	Germany	DM 1,606,442	43	889,336	111,144
Andean Regional Project on Irrigation and Environmental Management To help irrigation agencies assess the environmental impacts arising from the expansion of upstream irrigation.	Inter-American Development Bank	500,000	24	Nil	147,598
Research Support To carry out the review and planning for IIMI's work in conjunctive use management and to produce a study of farmer involvement in seasonal water allocation in large systems in South Asia based on comparisons of systems already studied by IIMI in Sri Lanka and India.	India	37,393	12	Nil	24,810
Performance Assessment Program Support for the performance assessment program which aims to develop and validate generally accepted conceptual frameworks, methodologies and indicators that can be used for assessing and improving the performance of irrigated agriculture.	Japan	J.Yen 30,432,000	12	Nil	300,000
Environment Program Support for the environment program which aims to develop environmental indicators, measuring and quantifying environmental impacts of irrigation, case studies to validate developed methodologies and training master's level candidates.	Japan	J.Yen 20,288,000	12	Nil	27,785

Restricted Projects 1995 *(Continued)*

Project	Donor	Pledged amount*	Duration (months)	Cumulative expenditure* to 31/12/1994	Expenditure* 1995
Gender Issues in Irrigation Management To increase knowledge and understanding about the relationship between gender relations and the performance of irrigation systems.	The Netherlands	DFL 300,600	36	87,459	20,428
Managing Irrigation for Environmentally Sustainable Agriculture in Pakistan Support for studies of Long-Term Salinity Trends in the Punjab; Salinity and Waterlogging Studies in other provinces and Institutional Initiatives.	The Netherlands	NLG 5,752,000	60	112,382	684,499
Design and Environmental Management Interventions for Vector Control To support an ongoing study being implemented by IIMI aimed at reducing the transmission of vector-borne diseases in irrigated areas through community-based management interventions.	Royal Norwegian Embassy (NORAD)	51,000	19	Nil	7,781
Sub-Saharan Africa To develop a reinforced strategy and plan of action for working on water-related issues in the Horn of Africa.	USAID	36,031	12	Nil	16,631
Shared Control of Natural Resources (SCOR) To assist Sri Lanka to sustain the productivity of land and water resources within selected watersheds through shared control by local user groups and the government, involving formal agreements and joint management.	USAID	5,995,800+ SL Rs 27,755,000	64	1,395,886	1,047,292
Inter-Center Initiative on Water Resource Management To support a program that will be working at the nexus of natural resource management and agriculture, seeking to make more rational use of fresh water.	Australia	21,528	12	Nil	21,528
	Danida	49,985	12	Nil	49,985
	France	41,645	12	Nil	41,645
	Rockefeller	25,000	12	Nil	25,000
	USAID	13,969	12	Nil	13,969
Complementary					
Monitoring and Evaluation of Participatory Irrigation and Systems Management To assist the Government of Sri Lanka and the irrigation agencies in the implementation of the government's new participatory irrigation system management policy through comprehensive monitoring and evaluation of the Turnover Program being implemented in selected schemes.	Asian Development Bank	595,000	30	560,143	34,857

Restricted Projects 1995 *(Continued)*

Project	Donor	Pledged amount*	Duration (months)	Cumulative expenditure* to 31/12/1994	Expenditure* 1995
Pehur High-Level Canal Project Support for joint activities involving the Irrigation Department, the Government of the North-West Frontier Province and IIMI.	Asian Development Bank	833,800	84	Nil	20,101
Sri Lanka TA-Phase II To strengthen the long-term viability of irrigation systems and to optimize the use resources through implementing, refining and evaluating management recommendations developed under Phase I for system management, operation and maintenance; system rehabilitation and improvement; and strengthening irrigation agencies and farmer organizations, with particular attention to the requirements for crop diversification.	Asian Development Bank	750,000	57	744,716	5,284
Fellowship Training for Two FAO Fellows from India A three-month course of training in water management for two FAO Fellows from India.	Food and Agriculture Organization	8,523	12	Nil	546
Director General's Recruitment Support to help IIMI to recruit a new Director General.	Ford Foundation New York	130,000	18	40,690	89,310
Director General's Sabbatical Leave Partial support for research on irrigation management issues.	Ford Foundation New York	27,500	18	Nil	5,723
Nigeria-Phase II Support for an irrigation management program in Nigeria.	Ford Foundation New York	325,000	24	319,925	5,075
Mexico-Phase II Support for collaborative research on transfer of irrigation systems in Mexico.	Ford Foundation New York	200,000	12	Nil	Nil
Kirindi Oya Irrigation and Settlement Project Impact Assessment Study (KOISP) Study on crop and livestock management practices and the associated production marketing problems including farm budgets and yields; forestry in KOISP; sanitation, water supply, nutrition and health aspects of the settlers/settlement including the assessment of water quality and status of irrigation structures, their use status, soil erosion, siltation, and other irrigation-related subjects.	Sri Lanka	32,499+ SL Rs 3,917,500	19	89,397	22,587

Restricted Projects 1995 *(Continued)*

Project	Donor	Pledged amount*	Duration (months)	Cumulative expenditure* to 31/12/1994	Expenditure* 1995
National Workshop on Nongovernmental Agencies (NGOs) Workshop on the role of nongovernmental organizations in irrigation development and management.	International Labour Organisation Nepal	5,951	24	2,660	3,291
Fordwah Eastern Sadiqia (South) Irrigation and Drainage Project The study of the services of IIMI Pakistan were contracted by WAPDA to collaborate in the proposed research and monitoring activities through the membership of the Umbrella Technical Group and for the preparation of an Integrated Research Plan.	Pakistan	123,550	54	29,456	35,229
Strengthening Irrigation Management in Egypt To develop a plan whereby MPWWR can make effective use of IMS outputs which would be reflected in future assistance programs, make further progress toward the establishment of a cost-recovery program needed for sustainable efficient water use, and achievement of other water resource management objectives.	USAID	1,325,000	16	12,070	1,236,770
Supplementary Project for Strengthening of the Left Bank Outfall Drain (LBOD) Stage-I To test the viability of farmers' managing parts of the irrigation systems, more specifically distributary/minor canals so that more efficient and equitable allocation of water can be achieved; and to make recommendations on future extensions from the results of the pilot projects.	World Bank	1,257,590	30	Nil	317,047
Evaluation of the National Water Management Project Aims at increasing productivity and farm incomes in existing irrigation schemes through a more reliable, predictable and equitable irrigation service.	World Bank	160,000	17	76,302	83,698

*In US dollars unless otherwise stated.

DONORS 1995

During 1995, IIMI's funding support was provided by the following governments, development banks, agencies and foundations:

- Australia
- Canada
- Denmark
- France
- Germany
- Japan
- Norway
- Spain
- The Netherlands
- USA
- African Development Bank
- Asian Development Bank
- Inter-American Development Bank
- International Bank for Reconstruction and Development (World Bank)
- European Union
- Food and Agriculture Organization
- Ford Foundation
- International Labour Organisation
- Rockefeller Foundation

The Governments of Bangladesh, Burkina Faso, Colombia, Egypt, India, Mexico, Nepal, Niger, Nigeria, Pakistan, Sri Lanka, Sudan, and the Philippines provided program support for IIMI-related activities in those countries.

BOARD OF GOVERNORS 1995

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Randolph Barker *(ex officio)*
(from 1 January to 31 August 1995)
Interim Director General
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David Seckler *(ex officio)*
(from 1 September 1995)
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910 Nanihale Place
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International Agriculture Development
Faculty of Agriculture
Kinki University
3327-204 Nakamachi, Nara
Japan

SENIOR RESEARCH ASSOCIATES 1995

IIMI's senior research associates are internationally recognized experts in their fields and commit part of their time directly in IIMI's research activities.

Bos, M.G. *The Netherlands*
Engineer

Carruthers, Ian *UK*
Economist

de Los Reyes, Romana *The Philippines*
Anthropologist

Frederiksen, Harald *USA*
Engineer

Keller, Jack *USA*
Engineer

Kikuchi, Masao *Japan*
Economist

Lesaffre, Benoît *France*
Engineer

Levine, Gilbert *USA*
Engineer

Panabokke, C.R. *Sri Lanka*
Soil Scientist

Rogers, Peter *USA*
Engineer

Ruttan, Vernon *USA*
Economist

Wade, Robert *UK*
Political Scientist

INTERNATIONAL STAFF 1995

Office of the Director General

Lenton, Roberto—*Argentina*
Director General
(until 30 June 1995)

Mohtadullah, Khalid—*Pakistan*
Deputy Director General
(until 31 May 1995)

Barker, Randolph—*USA*
Interim Director General
(from 1 January 1995 to 31 August 1995)
Director, National & Special Programs
(from 1 September 1995)

Seckler, David—*USA*
Director General
(from 1 September 1995)

Programs Division

Kijne, Jacob—*The Netherlands*
Director for Research
(Until 31 December 1995)

Skogerboe, Gaylord—*USA*
Director for Pakistan

Bandaragoda, D. Jayatissa—*Sri Lanka*
Senior Management Specialist, Pakistan

Bhatia, Ramesh—*India*
Program Leader, Performance, Sri Lanka

Brewer, Jeffrey—*USA*
Irrigation Specialist, Sri Lanka

de Klein, Christiana Helena—*The Netherlands*
Associate Expert, Pakistan
(seconded through the Ministry of Finance, Revenue & Economic Affairs, The Hague)
(from 25 July 1995)

Garces-Restrepo, Carlos—*Colombia*
Irrigation Management Specialist
(Transferred to Colombia [CIAT] w.e.f. 1 April 1995)

Gosselink, Paul—*The Netherlands*
Associate Expert, Sri Lanka

Haq, K. Azharul—*Bangladesh*
Irrigation Specialist, Sri Lanka

Johnson, Sam—*USA*
National Program Leader, Mexico

Kalwij, Ineke Margot—*The Netherlands*
Associate Expert, Pakistan
(seconded through the Ministry of Finance, Revenue & Economic Affairs, The Hague)
(from 22 April 1995)

Kato, Kazunori—*Japan*
Irrigation Specialist, Sri Lanka

Kloezen, Wim—*The Netherlands*
Associate Expert
(Transferred to Mexico w.e.f. 1 July 1995)

Konradsen, Flemming—*Denmark*
Associate Expert, Sri Lanka

Kuper, Marcel—*The Netherlands*
Associate Expert, Pakistan

Lonsway, Kurt—*USA*
Irrigation Specialist and Project Leader, Niger

Merrey, Douglas—*USA*
Team Leader, Egypt

Perry, Christopher—*United Kingdom*
Irrigation Specialist, Sri Lanka

Pradhan, Ujjwal—*Nepal*
Assistant Irrigation Specialist/Acting Head of Nepal Field Operations
(until 31 March 1995)

Renault, Daniel—*France*
Irrigation Specialist, Sri Lanka
(seconded through the Ministry of Agriculture, France from 3 April 1995)

Rey, Jacques—*France*
Associate Irrigation Specialist, Sri Lanka
(until 30 April 1995)

Rinaudo, Jean-Daniel—*France*
Asst. Agricultural Economist, Pakistan
(seconded through the Ministry of Foreign Affairs, France from 3 May 1995)

Sakthivadivel, R.—*India*
Senior Irrigation Specialist, Sri Lanka

Sally, Hilmy—*Sri Lanka*
Irrigation Specialist and Project Leader, Burkina Faso

Shafique, Muhammad S.—*Pakistan*
Head, Sudan Field Operations
(Transferred to Pakistan w.e.f. 15 June 1995 as Irrigation Specialist)

Strosser, Pierre—*France*
Irrigation Specialist, Pakistan

Vermillion, Douglas—*USA*
Irrigation Specialist, Sri Lanka

Wijayaratna, C.M.—*Sri Lanka*
National Program Leader, Sri Lanka

Yashima, Shigeo—*Japan*
Irrigation Specialist, Sri Lanka

Zwarteveen, Margreet—*The Netherlands*
Associate Expert/Gender Specialist

Communications Division

Fuchs-Carsch, Marian—*USA*
Head, Donor Relations & Project Development

Lenahan, James—*United Kingdom*
Head of Information

Finance and Administration Division

Nancy O. Andrews—*USA*
Director, Finance and Administration
(until 30 September 1995)

SELECTED PUBLICATIONS 1995

Journal Articles and Other Reviewed Papers

Aslam, M. and G.V. Skogerboe. 1995. Irrigation system salinity management modeling. Water Resources Development, 11(3):261–272.

Athukorale, K. and M. Zwarteveen. 1995. Participatory management: Who participates? The Island, 1&8 January: pp.20; pp.22.

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Merrey, D.J. 1995. Potential for devolution of management to farmers' organizations in an hierarchical irrigation management agency: The case of the Mahaweli Authority of Sri Lanka. In Muller, H.P.; Hettige, S.T. (Eds.), The blurring of a vision - The Mahaweli: Its social, economic and political implications. Ratmalana, Sri Lanka: Sarvodaya. pp.222–243.

Oorthuizen, J. and W.H. Kloezen. 1995. The other side of the coin: A case study on the impact of financial autonomy on irrigation management performance in the Philippines. Irrigation and Drainage Systems, 9:15–37.

Perry, C.J. 1995. Determinants of function and dysfunction in irrigation performance, and implications for performance improvement. Water Resources Development, 11(1):25–38.

Waheed, uz-Z. 1995. Modelling of sediment transport in river system. ICID Journal, 44(2):109–117.

Zwarteveen, M. and N. Neupane. 1995. Gender aspects of irrigation management: The Chhattis Mauja Irrigation System in Nepal. Asia-Pacific Journal of Rural Development, 5(1):1–26.

Zwarteveen, M. 1995. Linking women to the main canal: Gender and irrigation management. London, UK: IIED. 18p. (Gatekeeper series no.54).

Newsletters

FMIS Newsletter. No.13. September 1995. 52p. (ISSN 1012-988x).

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IIMI. Burkina Faso. Namanegdzanga: Irrigation et environnement. (National language newsletter on irrigation and the environment) No.4, March 1995. (ISSN 1022-6346).

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IRMU Newsletter. Vol.2, No.1. Colombo, Sri Lanka. Irrigation Research Management Unit, Irrigation Department, Sri Lanka. (January 1995). 8p.

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ITIS. Irrigation Techniques for Irrigation Systems. Vol.2, No.1. Colombo, Sri Lanka: IIMI. (September 1995). 32p. (ISSN 1024-2570).

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