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Economic issues regarding tertiary canal improvement programs, with an example from Egypt

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Abstract. Public investments in farmer-managed tertiary canals can promote an improved distribution of water among farmers, enabling them to improve water management practices, enhance crop yields, and select from a wider variety of cropping choices. This paper examines economic issues regarding public programs designed to improve or rehabilitate tertiary canals, particularly in developing countries. Key issues include defining property rights to irrigation water or delivery capacity, and to new or improved irrigation facilities; communicating the relative scarcity of agricultural inputs with appropriate prices or allocations; implementing cost recovery; and determining the best mix of public and private sector participation. The transaction costs of implementing market-oriented programs are also discussed. Economic issues are illustrated by describing Egypt's national Irrigation Improvement Project, for which a set of alternative cost recovery programs is presented.

Key words: cost recovery, Egypt, irrigation economics, mesqas, rehabilitation, tertiary canals, water policy

Introduction

Public investments in irrigation systems have declined in recent years, after increasing through the 1970s. For example, World Bank lending for irrigation projects declined from a peak of just less than $2 billion per year (in constant 1991 dollars) in 1978 to about $1 billion per year in 1992 (Jones 1995). International lending and assistance for irrigation projects in Asia declined by more than 50% from the late 1970s to the late 1980s (Rosegrant & Svendsen 1993).

Factors contributing to the decline in public spending include large public and foreign debt loads, political resistance from environmental groups, rising real costs of new irrigation development, and declining real prices for food grains (Rosegrant & Svendsen 1993). In addition, the performance of many irrigation systems has not been as good as expected when the systems were designed and constructed (Repetto 1986; Plusquellec et al. 1990; Kelley & Johnson 1991; Small & Carruthers 1991, Ch. 1; Easter 1993), and governments generally have not been successful in recovering the capital costs of construction or the operation and maintenance costs from farmers (Easter 1990; Johnson 1990; Afzal 1996; del Castillo 1997). Failure to collect funds for operation and maintenance has contributed to the poor performance of irrigation systems (Sampath 1992) and to the decline in public funding for irrigation projects (Gulati et al. 1994).

The decline in public spending has generated concern among some authors regarding the outlook for sustaining food production in future. For example, Carruthers, Rosegrant, and Seckler (1997) suggest that declining real food prices and a generally satisfactory aggregate food supply have generated a potentially harmful sense of food security in which food production is expected to keep pace with increasing food demand, over time. They suggest that further investments in irrigation systems are required to reduce the probability of food shortages, to avoid high food prices in future, and to increase food supplies in regions where income or resources remain inadequate to provide basic food requirements.

Albertson and Bouwer (1992) suggest that existing irrigation projects must be rehabilitated to increase food production, as part of a balanced development strategy. Easter and Welsch (1986) suggest that investments in canal lining, control structures, field ditches, and measurement devices are needed in many existing systems to improve water control and reliability. Such efforts may be more cost-effective than building new irrigation systems, particularly when seeking to achieve specific goals, such as reducing seepage losses, salinization, and waterlogging (World Bank 1992). Svendsen and Meinzen-Dick (1997) suggest that rehabilitation investments will remain attractive to donor agencies in future, given the relatively large rates of return for such projects, particularly when initial investments are treated as sunk costs. They also suggest that institutional changes and policy reform will dominate future efforts to improve water management.

Policy makers and water resource agencies must evaluate investment opportunities and identify situations in which limited public funds can be used to generate net benefits. Improving water distribution in tertiary delivery systems may generate public and private benefits by enhancing the security of water deliveries, particularly among farmers located farthest from main and secondary canals. In many countries tertiary canals are operated and maintained by farmers, either individually or collectively in water user associations. The lack of well-defined property rights to tertiary canals, and to the irrigation water they carry, results in poorly maintained facilities and inequitable distribution of water among farmers. Efforts to improve water distribution and reduce insecurity may increase aggregate production substantially (Bromley et al. 1980).

Several authors have examined the economic and cultural implications of inequitable water distribution among farmers at the head ends and tail ends of tertiary canals (Skold et al. 1984; Chambers 1988; Uphoff et al. 1990) and among villages or communities located at different sites along secondary or main canals (Wade 1988; De Veer et al. 1993; Price 1995; Uphoff 1996). Recommendations for improving distribution include improvement of physical structures to provide better measurement capability and formation of water user associations to operate and maintain tertiary canals, while collecting appropriate fees from farmers. The public cost of supporting such projects is a function of public agency involvement in design and construction, and in efforts to form local organizations (Coward & Uphoff 1986).

This paper examines economic issues regarding the design and implementation of tertiary canal improvement projects. Pertinent issues include defining property rights to irrigation water or delivery capacity, and to new or improved irrigation facilities; communicating the relative scarcity of agricultural inputs with appropriate prices or allocations; implementing cost recovery; and determining the best mix of public and private sector participation. The transaction costs of implementing market-oriented programs are also addressed. Conceptual discussion of these issues precedes a description of Egypt’s Irrigation Improvement Project, for which a set of cost recovery programs is presented.

Economic issues

The public’s goal in supporting irrigation is to enhance the social and economic values of agricultural production by expanding the set of crops available to farmers in arid regions, extending the production season, and increasing yields. The returns to public investments in irrigation projects will be maximized when systems are operated and maintained correctly, and when farmers make optimal choices regarding inputs and outputs. Several conditions must be satisfied for this to occur, including the definition and enforcement of property rights to water and to farmer-managed irrigation facilities. In addition, agricultural output prices and farm-level prices or allocations of inputs must reflect relative scarcity conditions. For example, if water supply or delivery capacity is scarce, relative to demand, that scarcity must be reflected in the price or allocation of water or delivery capacity to encourage farmers to choose optimal amounts of those resources.

The public cost of improvements in tertiary systems can be reduced by implementing a successful cost recovery program in which farmers reimburse the government or donor agencies for a portion of design and construction costs, and when farmers are responsible for operation and maintenance.

Private sector involvement in design, construction, and operation can often reduce the cost of conducting those activities. Government agencies can be helpful in supporting private sector efforts, while reducing public expenditures for tertiary system improvements.

Property rights

Clearly defined property rights are essential components of a market economy in which private firms and consumers are expected to use resources efficiently (Stiglitz 1997, pp. 30–33). In the absence of such rights, government intervention is required to allocate or protect scarce resources using some other mechanism. For example, if property rights to irrigation water are not defined and enforced, mis-allocation of water can generate conflicts among farmers, resulting in sub-optimal use of the resource (Hunt 1990; Ghosh & Lahiri 1992; Tang 1994; Anderson & Snyder 1997, p. 23). Similarly, the likelihood that irrigation canals and pump stations will be operated and maintained correctly, over time, can be enhanced by assigning ownership of the facilities to an individual, association, or community. Long-term contracts or use agreements that guarantee access and use of irrigation facilities can produce the same result.

Several authors have described the importance of property rights in community-level and farmer-managed irrigation systems. For example, Coward (1986a) suggests that irrigation development efforts can be improved by considering more explicitly the relationship between property rights and irrigation performance. He notes that public agencies implementing irrigation improvement projects must avoid destroying the existing property relationships and replacing or confusing those with state-held property rights that alienate water users from the facilities and remove their incentive for engaging in collective irrigation activities. Coward (1986b) recommends that governments support local development goals indirectly, with subsidies or grants, and that property rights to new or improved facilities be assigned to local groups.

Hecht (1990) presents a socio-economic methodology for examining property rights issues at the earliest stages of project development. He suggests that pre-existing systems of property rights to land and water place bounds on the set of socially acceptable arrangements regarding system design, water scheduling, and water allocation. Van Steenbergen (1992) extends Hecht's recommendations by suggesting that project officials must consult closely with water users when an irrigation improvement project increases the volume of water available or reduces relative scarcity, as such changes can lead to reallocation of land and water rights within a project command area.

Property rights can be assigned to individuals or to groups of farmers, such as water user associations (Wade 1987). In either case, the individuals or associations will have an incentive to maximize the net benefits generated by their activities (Hayami 1997, p. 184). Well-defined property rights to water can motivate farmers to manage community irrigation systems more carefully and to participate more actively in irrigation improvement projects funded by government agencies (Hunt, 1990; Meinzen-Dick & Mendoza 1996). Chand (1994) makes the following observation in the state of Himachal Pradesh, India, after comparing two small-scale farmer managed delivery canals (*kuhls*). Water rights are defined along one of the two *kuhls*:

> A well-defined regime of water rights creates interest with responsibility in kuhl management, besides a sense of security of income and production benefit from the kuhl water. It is found that kuhl systems without water rights neither have orderly distribution of water nor could there emerge any users organisations to maintain and operate the system.

Well-defined water rights give farmers an economic incentive to participate in the operation, maintenance, and improvement of the delivery system in which their water supply is transported.

Relative scarcity

Economists consider a resource to be scarce when the quantity demanded at a zero price exceeds the available supply at some time or location (Boyes & Melvin 1996, p.4). A rationing mechanism is required to allocate scarce resources among those who wish to obtain them, to prevent non-productive conflicts. Markets allocate scarce resources efficiently, as individual firms and consumers must compare their incremental gains with the same prices charged to all other firms and consumers. Market prices adjust, over time, with changes in supply and demand, without government intervention. By contrast, managers of centrally planned economies in which prices are not allowed to reflect market conditions allocate scarce resources using quotas that rarely generate an efficient allocation among competing users.

Failure to communicate relative scarcity conditions can encourage firms and individuals to choose non-optimal combinations of inputs and outputs, often at some cost to the public. For example, if irrigation water or delivery capacity is limited, but no prices or allotments are used to allocate either resource efficiently, the sum of net benefits generated in irrigation will be less than optimal. This will occur because some farmers will be successful in gaining access to a relatively large amount of water or delivery capacity, while others may obtain little or none of those resources. As a result, the incremental net value of the scarce resources will be greater on some farms than on others, and the sum of net gains will not be maximized.

Many irrigation communities have developed methods to allocate scarce water resources among farmers without using prices or formal markets (Chambers 1988, Ch. 2; Tang 1994; Upton 1996, Ch. 9). Examples include the *warabandi* system in Pakistan (Easter & Welsch 1986;), the *subak* system in Bali, Indonesia (Sutawan 1989), and the *entornador-entornador* system in the Cape Verde Islands (Langworthy & Finan 1996). While communal and bureaucratic allocation schemes have operated successfully for many years, they cannot guarantee that economic efficiency is achieved (Upton 1996, Ch. 9). In addition, recent changes and interventions in the historical *subak* and *warabandi* systems have raised questions regarding the equity of water allocation among farmers (Qureshi at al. 1994; Horst 1996: Bandaragoda 1998).

Water pricing programs can be designed to achieve various goals including economic efficiency, cost recovery, and reduction of deep percolation and drain water volume. The impact of water pricing on farm-level decisions varies with the type of program chosen (Small 1989; Sampath 1992). Tsur and Dinar (1997) review several water pricing alternatives, including volumetric, area-based, and block-rate structures. Bos and Wolters (1990) report that water is priced by volume in 60% of the irrigation projects they surveyed in the early 1980s, while 25% of the districts use volumetric pricing, and fewer than 15% use a combination of area and volume. Volumetric pricing is common in California, where rates vary among irrigation districts according to the costs of obtaining water supplies, delivery costs, and capital repayment obligations (Cummings & Nercessiantz 1994; Tsur & Dinar 1997). Water pricing structures vary throughout India, while surface water is priced by volume in the Jordan Valley, and farmers in Pakistan and Turkey pay annual, area-based fees that vary by crop and region (Chaudhry et al. 1993; Tsur & Dinar 1997).

Formal and informal water markets can also be effective in communicating relative scarcity values among potential buyers and sellers, by providing farmers with an opportunity to lease or sell a portion of their water supply for a specific time interval or in perpetuity (Dudley 1992; Rosegrant & Binswanger 1994; Rosegrant et al. 1995; Dinar et al. 1997). Efficient water markets require that property rights to water, or water use rights, are defined and enforced (Winpenny 1994, p. 57; Hearne and Easter, 1995; Perry et al. 1997). Water markets in California (Cummings & Nercessiantz 1994; Howitt 1994; Howitt & Vaux 1995), Chile (Gazmuri 1994; Gazmuri & Rosegrant 1996), India (Janakarajan 1993; Shah 1993; Saleth 1996; Shah & Ballabh 1997), and Pakistan (Chaudhry 1990; Meinzen-Dick 1994) have improved the productivity of water resources while providing farmers with income-enhancing opportunities.

Describing international experience with water markets, Briscoe (1997) concludes that “from a conceptual, practical and political perspective, the appropriate approach for ensuring that the scarcity value of water is transmitted to users is to clarify property rights and to facilitate the leasing and trading of these rights.” Svendsen and Meinzen-Dick (1997) include a “net shift of authority for allocating water use rights from public agencies to the use right holders themselves through private transactions and arrangements” in their list of themes regarding future water management policies and institutions. Rosegrant (1997) suggests that the most important water policy reforms will involve changing the institutional and legal environment in which water is supplied to one that enables individuals to make their own decisions regarding water use, while at the same time presenting them with the true scarcity value of water.

Cost recovery

Efforts to recover the costs of public investments in farmer-managed irrigation systems are consistent with defining property rights to the new or improved facilities and communicating relative scarcity of resources used in construction. The total cost of improvement projects can be reduced when farmers are required to pay for the improvements and are included in project design and construction activities (Coward & Uphoff 1986; Lowdermilk 1986). Discussions with farmers regarding cost recovery will enhance their understanding of the relative scarcity of key resources, including irrigation water, delivery capacity, and the fixed and variable inputs required to improve irrigation systems (Small & Carruthers 1991, p 52).

The appropriate form of a cost recovery program and optimal parameter values can be determined in conjunction with program goals. Rhodes and Sampath (1988) examine the cost recovery implications of several water pricing and allocation schemes in developing countries. They conclude that volumetric water pricing is the best cost recovery method if the government’s goals include efficiency, equity, and cost recovery. Among other options, area-based pricing is superior to input or output taxation. Transaction costs must also be considered, as these will vary among alternative programs.

Legislation in many countries authorizes public agencies to recover capital costs and to require farmers to pay for operation and maintenance, though in many cases political and practical issues have limited the success of cost recovery efforts. Del Castillo (1997) reviews the recent experience in five countries receiving World Bank assistance with irrigation projects. Brazil requires farmers who benefit from such projects to pay water charges that include a volumetric component for operation and maintenance and an area-based charge to recover the public's investment in off-farm irrigation facilities. Chile requires farmers to repay net investment costs in proportion to their share of water rights. Cost recovery targets are reduced for small farmers in marginal areas and those in extreme poverty.

In Korea, farmland improvement associations have been formed to recover costs from farmers for publicly funded irrigation projects that have been transferred to the associations. Capital cost repayment obligations vary according to the degree of improvement provided by the project. Volumetric water rates in Peru include three components: 1) a water user association fee to generate funds for operation and maintenance, improvement of facilities, and administrative costs; 2) a water levy that is 10% of the first component; and 3) a fee to recover the amortized cost of public investments in irrigation storage facilities, which is also 10% of the first component in most cases. In practice, however, the water rates are too low to fund proper operation and maintenance, and the amortization component often is not recovered.

In Mexico, farmers are responsible for operation and maintenance of tertiary and secondary canal systems, and they must contribute financially for government operation of main systems (Spencer & Subramanian 1997). Mexico requires farmers to pay up to 90% of reimbursable investment costs (del Castillo 1997) and collection of water fees, as a proportion of operation and maintenance costs, has increased from less than 6O% in 1991 to about 80% in 1994, following the transfer of operation and maintenance responsibilities to water user organizations (Gorriz et al. 1995). Indonesia has implemented an irrigation service fee program to raise revenue for operating and maintaining large irrigation systems, while encouraging farmers in small systems to accept responsibility for operation and maintenance (Johnson 1995).

Public and private sector participation

Public involvement in irrigation projects is appropriate when public benefits are generated by irrigation, and when public assistance increases the pace at which desirable projects are implemented. Public spending can also be justified by positive spillover effects, such as technological advances, and by efforts to spread project costs among a large number of beneficiaries (Jaffee & Srivastava 1994; Hyman et al. 1997). Public agencies can reduce private transaction costs of project design and development by helping farmers to identify project opportunities, form water user associations, and define the scope of irrigation projects.

Meinzen-Dick (1997) suggests that governments can also be helpful in monitoring and regulating externalities and third-party effects of irrigation, maintaining a supportive legal framework for farmer organizations, and adjudicating water rights. Chand (1994) describes government intervention "to settle enforceable rights" in farmer-managed irrigation systems as "a vital role in creating orderly water distribution and in the formation of users organisation" in Himachal Pradesh, India.

Public agencies can encourage the formation of private firms to provide irrigation and drainage services, including design, construction, and operation and maintenance, by removing any institutional barriers that limit the registration or activities of private firms. For example, the Bangladesh Agricultural Development Corporation relinquished its control of the provision of lift irrigation services in the 1980s, allowing the entry of private firms (Johnson et al. 1998). Water users are pleased with the change in providers, noting that the availability and quality of farm inputs have improved. Public agencies can also provide information regarding the integrity and experience of individual firms during the early stages of private sector development, before the market system is able to provide that service on its own.

Historically, many governments have provided a larger public subsidy than was intended for irrigation projects by not recovering capital costs and by achieving only partial recovery of operation and maintenance costs. In recent years, several countries have increased their efforts to collect those costs from farmers, and some have begun transferring responsibility for operating and maintaining tertiary systems to water user associations. In most cases, the goals of management transfer programs are to reduce government expenditures and improve system performance (Johnson 1995; Lenton & Garces-Restrepo 1995; Turral 1995; Vermillion & Johnson 1995).

Policies that promote irrigation management transfer range from implementing irrigation service fees and fostering competition in service delivery to devolution of control and privatization of assets (Vermillion & Johnson 1995). Mexico began transferring tertiary canal responsibilities to irrigation districts in 1990, and as of 1996 the program includes more than 2.8 million ha of irrigated land (Johnson 1997). Turkey began slowly transferring operation and maintenance responsibilities to farmers in the early 1960s, but increased the pace of the program substantially in 1993 (Bilen 1995). The current goal is to include almost one million hectares in the program by the year 2000. The Turkish government expects to save from $10 million to $16 million per year in reduced expenditures. The Government of New Zealand sold 49 irrigation projects, ranging in size from 100 ha to more than 20,000 ha during 1988 through 1990, with the goal of ending its responsibility for operation and maintenance (Farley & Simon 1996). A survey of new water user organizations in 1993 found that water charges and operating costs had been reduced, and that operational performance had improved with the change of ownership.

Vermillion (1997) reviews 29 studies of irrigation management transfer programs and finds that the most often reported positive impacts are lower farm-level and government costs of irrigation, enhanced financial self-reliance of irrigation systems, expansion of service areas, lower water deliveries per hectare, and higher cropping intensities and yields. The most frequently cited negative results include higher farm-level costs, failing financial viability of lift systems, and deteriorating facilities. Although the results regarding farm-level costs and the condition of facilities are inconclusive, most authors of the 29 studies report positive program results.

Transaction costs

Some of the economic gains achieved by implementing water rights, a water pricing program, or a water market will be offset by transaction costs that include efforts to measure water deliveries, collect revenue from water sales, record market transactions, and protect water rights. Transaction costs of market activity include the costs of identifying viable purchase and sale opportunities, negotiating terms of agreements, and mitigating or compensating for any third-party impacts (Rosegrant & Binswanger 1994). The transaction costs of implementing water rights and pricing programs may be particularly high in developing countries where large irrigation systems deliver water to many small farms (Rosegrant & Binswanger 1994). Public agencies can reduce private transaction costs by collecting and sharing water market information, and providing an efficient and secure procedure for transferring water rights.

The administrative costs of water pricing, allocation, and marketing programs can be substantial, particularly in countries where improvements in delivery channels, measuring devices, and operational procedures are required to enable better control and measurement of water deliveries. Institutional enhancements may also be required to support volumetric water pricing and trading of water rights. However, administrative costs can be reduced by choosing the appropriate level at which to implement innovative programs and by adopting technological enhancements that support program goals. For example, Small (1989) and Meinzen-Dick & Rosegrant (1997) describe volumetric "water wholesaling" in which a public agency sells water to a group of users or a water user association at some point in the delivery system where volumetric measurement is feasible. The user group is then responsible for recovering water costs from individual members. Measurement capability might be extended to lower levels of the delivery system by designing and installing new metering devices that provide volumetric measurement at a reasonable cost (Martinez et al. 1994).

Egypt's Irrigation Improvement Project

The economic issues described above are examined further by reviewing Egypt's national Irrigation Improvement Project, which is designed to improve the distribution of water among farmers and encourage farm-level improvements in water management (Hvidt 1996; Depeweg & Bekheit 1997). Key features include replacement of earthen, below-grade mesqas (tertiary canals) with raised, concrete-lined mesqas or buried pipelines. Single-point pumping stations are installed to lift water from secondary canals into the concrete-lined mesqas or into storage tanks that serve the buried pipelines. Farmers are required to form water user associations to operate the pump stations, manage the delivery of water to farm ditches, and collect fees to reimburse the government for capital costs and to pay for operation and maintenance. A capital cost recovery plan has not yet been implemented.

The U.S. Agency for International Development provided financial support for the first phase of the Irrigation Improvement Project, in which tertiary canals serving about 24,000 ha were replaced or improved during 1986 through 1996. The World Bank, working with the Ministry of Public Works and Water Resources, is implementing a second phase of the project, beginning in 1997 and ending in 2002, with the goal of improving tertiary canals serving an additional 104,000 ha (World Bank 1994). The total area served by the USAID and World Bank projects will be about 5% of the irrigated farmland in Egypt.

The Irrigation Improvement Project has been justified economically on the basis of expected increases in crop yields on 60% of the land served by the improved mesqas (World Bank 1994). Water supply and reliability will improve for middle-reach and tail-end farmers, enabling them to maintain better soil quality, over time, and to match water deliveries with water requirements more accurately than is possible with un-improved mesqas. In addition, the Ministry hopes to reduce water losses through tail escapes at the ends of mesqas by converting the current rotational delivery system to a continuous flow regime by placing downstream flow control structures in secondary canals (Stoner 1994; El Quosy 1997; Hvidt 1998, p. 20).

Depeweg and Bekheit (1997) review some of the physical and engineering features of the Irrigation Improvement Project, including the improved mesqas, continuous flow, and downstream control structures. They evaluate the irrigation adequacy, reliability, equity, and efficiency of mesqa improvement alternatives from an engineering perspective. Hvidt (1996) examines the role of water user associations in improving the distribution of water among farmers along improved mesqas. The following discussion complements those studies by considering some of the economic issues that affect the equity of water distribution and the efficiency of water use.

Property rights

The Irrigation and Drainage Laws of Egypt assign ownership and responsibility for maintenance of mesqas to farmers, while the Ministry is responsible for system operation and maintenance through the secondary and branch canals (Allam et al. 1994; Aziz 1995; Hvidt 1998, p. 12). Granting the newly formed water user associations ownership status or providing them with long-term use agreements regarding the new mesqas and pump stations will enhance the likelihood that they will implement successful cost recovery programs to support operation and maintenance.

Property rights to irrigation water or to water delivery capacity would enhance the stature of water user associations and motivate farmers to maintain the viability of their associations. The potential role of property rights in allocating water efficiently among farmers on a single mesqa, and among water user associations, gains importance with the implementation of continuous flow and the installation of single-point pumping stations. In the past, farmers pumped water from below-grade mesqas during the rotation for their canal. With the new system, deliveries from the pump stations must be allocated among farmers, as the capacity is not sufficient for all farmers to withdraw water from a raised mesqa at the same time. Establishing property rights to water volume or delivery capacity among water user associations will encourage those groups to determine strategies for allocating water optimally among farmers.

Relative scarcity

In the Nile Valley and Delta, there is no charge for irrigation water (Hamdy et al. 1995; Attia 1997). Farmers on traditional mesqas must lift water about 1 to 2 meters from the below-grade canals, at their expense, but no funds are collected by the Ministry for operating and maintaining the main delivery system (Ward 1993; Nassar et al. 1996). Surface runoff and subsurface drain water are discharged from farms into regional drainage canals operated by the Ministry. There are no restrictions on the volume of water entering drainage canals (Ward 1993), and farmers are not charged the variable cost of providing drainage services (Okonjo-Iweala & Fuleihan 1993). The Ministry currently uses about 5 billion m^3 of commingled drainage water to augment water deliveries in locations where fresh water supply is limited (Abu-Zeid 1992; Abu-Zeid & Hefny 1992; Willardson et al. 1997).

At the national level, water is not yet a limiting resource for economic development in Egypt. When deep and shallow groundwater resources, drainage water, and treated sewage are added to the 55.5 billion m^3 available from the Nile River each year by agreement with Sudan, the total annual supply is 63.7 billion m^3, while annual water use is an estimated 61.7 billion m^3 (Simonovic et al. 1997). As a result, Egypt has not yet developed national irrigation water pricing or allocation policies that reflect scarcity conditions. However, such policies may be appropriate in some portions of the country where scarcity of water or delivery capacity constrains irrigation opportunities during some seasons or throughout the year (Radwan 1997).

Agricultural policy reforms beginning in 1986 have removed restrictions on cropping patterns and changed the relative prices of farm inputs and outputs, placing new pressures on water resources and delivery capacity in Egypt (El-Serafy 1993). In the past, cropping patterns were restricted and farmers were required to sell much of their output to the government at prices much lower than market levels (Khedr et al. 1996: Harik 1997, Ch. 4). The reforms allow farmers to choose cropping patterns freely, with the exception of cotton and sugarcane, and to sell their crops at market prices (Okonjo-Iweala 1993; World Bank 1993; Baffes & Gautam 1996). Many farmers have increased the area planted in rice each year, while reducing the area planted in cotton (Nassar et al. 1996; Fan et al. 1997). As a result, farm-level demands for water in the Nile Delta exceed the design capacity of the main irrigation system, which was not intended to support rice production on a majority of farm fields.

Current farm-level demands are based on a zero-price for water and reflect the lack of charges or allocations regarding delivery service, even though delivery capacity is limited. Communicating the relative scarcity of water or delivery capacity would encourage farmers to modify their cropping decisions and water demands to reflect the availability of limited resources. As noted above, communicating these scarcity conditions may be particularly appropriate when the rotational irrigation system is replaced with continuous flow.

The Irrigation Improvement Project, in conjunction with agricultural policy reforms, provides an excellent opportunity for implementing a program of water prices, allotments, or tradable water rights in the Nile Delta. The policy reforms have improved farm-level net revenue potential by removing restrictions on crop choices and eliminating the indirect taxation of agricultural output. The removal of subsidies for fertilizer and pesticides has raised farm-level costs (Khedr et al. 1996), but the net returns to major crop rotations have increased since the policy reforms were implemented (Okonjo-Iweala et al. 1993). The policy decision to remove fertilizer and pesticide subsidies provides a precedent for considering a similar policy regarding irrigation water.

The Irrigation Improvement Project includes installation of single-point pumping stations that can be metered easily to determine the volume of water withdrawn from secondary or branch canals by water user associations. Volumetric measurement of withdrawals would support either a water wholesaling program in which the associations purchase water from the Ministry, or a water allotment and tradable water rights program in which the available water supply or delivery capacity is allocated among associations. The associations would be responsible for collecting revenue from members to pay for their water supply and for allocating water equitably among farmers. These efforts are already within the scope of association activities, as they must collect revenue to operate and maintain the pump stations and they must allocate the limited pumping capacity among farmers.

A tradable water rights program could be designed initially to support the trading of water among water user associations. Over time, the program could evolve to support trades among individual farmers in different associations. The Ministry could record trading activity among associations using data from the single-point pumping stations, while associations record trades among farmers using their internal allocation procedures. In future, water delivery operations and trading could be coordinated by an organization representing all water user associations along a secondary canal, such as the federation of mesqa-level water user groups envisioned by the World Bank (1994). That organization could act as a clearing house for water supply and demand information, and arbitrate any disputes among associations.

Cost recovery

The initial version of the Irrigation Improvement Project was supported largely by the United States Agency for International Development, while the current version is supported by the World Bank and other donors. A portion of the World Bank funding is provided in a loan to the Government of Egypt, which has expressed its desire for farmers to repay a portion of the costs of implementing the Irrigation Improvement Project. During project appraisal, the Government and the World Bank agreed on the following cost recovery principles (World Bank 1994, p. 29):

- Farmers would repay the cost of pump stations during a period not exceeding five years,
- The cost of civil works would be repaid during a period of 10 to 20 years, based on farm-level ability to pay,
- Repayment would begin within the first year following completion of mesqa improvement,

- No interest would be charged on the investment costs repaid by farmers, and
- The Irrigation Advisory Service would be strengthened to support water user associations in financial matters.

Investment costs would be repaid by farmers to the government, while operation and maintenance costs would be paid directly to water user associations. The associations would determine the best method for recovering those costs, but they would be encouraged to implement fees pertaining to the volume or duration of water deliveries, to promote water use efficiency.

The estimated annual cost of repayment for the pump stations and civil works, over 15 years with no interest, is 160 Egyptian pounds (LE) per feddan ($112 per ha; World Bank 1994, p. 86), and the estimated operation and maintenance costs are LE 38 per feddan. The estimated farm-level reduction in the annual cost of pumping from below-grade mesqas is LE 58 per feddan, resulting in a potential net annual cost to farmers of LE 140 per feddan. The World Bank estimates that this cost represents 15% to 25% of the incremental farm-level income made possible by implementing the Irrigation Improvement Project. The estimated proportion varies by farm size and project area. Hence, it appears that farmers can afford to pay for the operation and maintenance costs and repay the investment costs according to the terms described above.

The Ministry and water user associations could recover the capital repayment and operation and maintenance costs by implementing assessments on land area, volumetric water prices, charges for irrigation events, or combinations of these alternatives. For example, the Ministry could assess each farmer's land at the rate of LE 160 per feddan, each year, while water user associations collect an additional LE 38 per feddan for operation and maintenance (Plan A in Table 1). Alternatively, water user associations could implement a volumetric price of LE 4.52 per 1000 m^3 to generate revenue for operation and maintenance (Plan B), assuming that farmers divert an average of 8400 m^3 per feddan during a two-crop rotation. The volumetric price could be adjusted as information is gained regarding farm-level price responsiveness.

The Ministry might prefer to collect the capital recovery funds directly from water user associations, rather than assessing farmland, to reduce their administrative costs and increase the likelihood that revenues will be made available to the Ministry. This could be accomplished either by requiring associations to pay the Ministry a fixed cost equal to LE 160 per feddan, or by implementing a volumetric water price of LE 19.05 per 1000 m^3 at the single-point pumping stations (Plan C). The associations would then be responsible for collecting revenue from farmers, using either land assessments, water

Table 1. Examples of cost recovery plans for Egypt's Irrigation Improvement Project, using costs as estimated in 1994.

	Plan and components	Assessment per feddan	Water price	Charge per irrigation event
		(LE/year)	(LE/1000 m^3)	(LE/feddan)
A.	Assessments per feddan			
	• Capital recovery	160.00	–	–
	• Operation and maintenance	38.00	–	–
B.	Assessment per feddan			
	• Capital recovery	160.00	–	–
	Volumetric water charge			
	• Operation and maintenance	–	4.52	–
C.	Volumetric water charges			
	• Capital recovery	–	19.05	–
	• Operation and maintenance	–	4.52	
D.	Irrigation event charges			
	• Capital recovery	–	–	10.00
	• Operation and maintenance	–	–	2.38

Notes: The capital recovery and operation and maintenance cost estimates in Plan A are from the World Bank Appraisal Report (1994), page 86. These are used to determine parameter values for Plans B, C, and D.

The water charges in Plans B and C are determined by assuming that farmers deliver 8400 m^3 per feddan during a two-crop rotation.

The irrigation event charges in Plan D are determined by assuming that farmers irrigate each of two crops 8 times per season.

The exchange rate during 1994 through March 1998 has remained near 3.39 Egyptian pounds (LE) per U.S. dollar and the estimated cumulative increase in the consumer price index for Egypt from July 1, 1994 through June 30, 1997 is 29.7% (EIU 1998).

One feddan is equivalent to 0.42 hectares.

prices, or irrigation event charges. The pertinent event charges are LE 10.00 for capital recovery and LE 2.38 for operation and maintenance, assuming that farmers irrigate 16 times during a two-crop rotation (Plan D).

Recovering capital costs by implementing a volumetric water price at single-point pumping stations provides an incentive for associations to manage their withdrawals and deliveries efficiently, and to pass along the concept of volumetric water charges to individual farmers. Water prices or allotments will encourage pump station operators to minimize the volume of water lost through tail escapes by operating the system to match farm-level demands as closely as possible. A volumetric charge for farmers can be simulated by estimating the volume of farm-level deliveries using flow rates and the duration of diversions from mesqas. Such an effort would likely be consistent with an association's internal water allocation program.

Acceptance of a volumetric water wholesaling program might be enhanced by offering associations an incentive to install and maintain water meters, and to provide accurate diversion data. For example, the Ministry might forgive a portion of the capital recovery costs if an association installs and maintains a water meter. As an illustration, the equivalent volumetric charge might be reduced from the LE 19.05 per 1000 m^3 in Plan C to LE 18.05 per 1000 m^3. The Ministry could charge the higher price initially, while offering the LE 1.00 per 1000 m^3 as a rebate each year, if an association services and calibrates its pump and water meter. The appropriate parameter values for the program would be determined by the cost to associations of installing and maintaining the equipment and the Ministry's administrative costs.

Compliance with pump and meter maintenance requirements could be verified annually by a certified technician. Private firms would likely be formed to meet the demand for pump and meter services, given the large number of mesqas and associations in the Nile Delta. The Ministry could maintain quality control by testing and calibrating a random sample of association pumps and meters each year. That task and certification of technicians could be performed by the Irrigation Advisory Service, which already works with water user associations.

Implementing cost recovery for the Irrigation Improvement Project would generate useful information regarding the potential costs and implications of a similar plan to recover the main system operation and maintenance costs from farmers throughout Egypt. The estimated agricultural component of those costs in the Nile Delta is LE 75 per feddan, or LE 10.70 per 1000 m^3 of irrigation water (ISPAN 1993; Allam et al. 1994; Perry 1996). An annual charge of LE 75 per feddan would reduce farm net incomes by an estimated 4.5% to 6.5%, depending on land rental rates (Perry 1996). This cost could be recovered through a volumetric water charge imposed at the pump stations of improved mesqas, providing an additional economic incentive for farmers and water user associations to manage water supplies efficiently.

Public and private sector participation

In areas where the net benefits of the Irrigation Improvement Project are positive, a faster rate of implementing the program may be desirable. This might be achieved by reducing the direct role of donor agencies and the government in the Irrigation Improvement Project, while stimulating private sector design, construction, and support activities (Goldensohn et al. 1995). Much of the technology installed in the Project has been used for many years and is readily available from private sector sources. For example, concrete J-sections for the raised mesqas, pipeline materials and alfalfa valves for the buried pipelines, and low-lift pumps for single-point pumping stations can be obtained and installed by private firms. Operating in a competitive business environment, the firms would be motivated to perform efficiently, while providing high quality service to water user associations, given the potential for extending their business throughout a large irrigated area.

Appropriate roles for the Government of Egypt in stimulating private sector involvement include:

- Reducing information and bargaining costs for private firms, by helping to form water user associations and participating in initial discussions involving those associations and private firms;
- Reducing the information costs for water user associations by maintaining information describing the experience of private firms in the Irrigation Improvement Project;
- Implementing a certification program for private firms providing design, construction, and support services, until the market for services develops sufficiently to account for uncertainty without government intervention;
- Reducing uncertainty and risk for private firms by providing guaranteed loans for water user associations; and
- Constructing rural roads, regional irrigation command centers, and other infrastructure to support private sector activity.

The government might also consider providing low-interest loans to water user associations, if the public benefits of irrigation improvements are sufficient to justify the public cost of providing such loans.

The World Bank (1994) plans to work with the Irrigation Advisory Service within the Ministry to establish federations of water user associations that would address inter-mesqa problems and coordinate interaction with the Advisory Service. The Ministry and the World Bank are also planning to establish command area centers for every 2,500 to 4,200 ha. The centers would provide a forum for farmers to meet with Advisory Service staff, pump manufacturers, mechanics, and irrigation engineers. The Ministry might encourage private sector firms, farmers, and representatives of water user associations to participate in command center activities. Information regarding private firms, including previous experience with irrigation projects and current prices for construction and repair services, could be made available to farmers at the command centers.

Summary

Public agencies can increase the likelihood that investments in farmer-managed irrigation systems will be successful by addressing several economic issues when designing and implementing improvement projects. In particular, property rights to water and to irrigation facilities can be assigned and enforced to encourage farmers and water user associations to manage resources carefully and maintain facilities, over time. In addition, the relative scarcity of irrigation water and delivery capacity can be communicated to farmers by implementing market-oriented policies, such as water prices, allotments, and tradable water rights, which encourage farmers to consider the scarcity value and opportunity cost of water deliveries when they select cropping patterns and irrigation methods.

Cost recovery programs can be implemented in cooperation with water user associations. The ability to recover costs can be enhanced by agricultural policy reforms that allow farmers to choose cropping patterns freely and receive market prices for their products. The costs of designing and implementing improvement projects can be reduced by working closely with farmers and water user associations, and by encouraging private firms to provide construction, operation, and maintenance services.

Egypt's Irrigation Improvement Project is being implemented at the same time that cropping patterns, input and output prices, and farm-level marketing opportunities are being liberalized by agricultural policy reforms. This combination provides an excellent opportunity to implement a viable cost recovery program that includes volumetric water pricing. A water wholesaling program could be implemented in which water user associations purchase water from the Ministry of Public Works and Water Resources, while passing those costs along to farmers. Incentives can be designed to encourage installation and maintenance of water meters at single-point pumping stations. Such a program would provide useful information regarding the potential to implement a similar effort for recovering main system costs throughout a wider region.

The conversion of Egypt's delivery system from rotational to continuous flow in selected areas, in combination with single-point pumping stations and improved mesqas, provides an opportunity to implement tradable water rights among water user associations and individual farmers. Associations must allocate limited delivery capacity among their members, who may choose to trade their water or delivery allotments for appropriate compensation. Such a program would promote allocative efficiency of irrigation water and delivery capacity, while enhancing the values generated by the Irrigation Improvement Project.

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