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Research Report

Charging for Irrigation Water: The Issues and Options, with a Case Study from Iran

C. J. Perry

International Water Management Institute

Research Reports

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Summary

Inadequate funding for maintenance of irrigation works and emerging shortages of water are prevalent. The use of water charges to generate resources for maintenance and to reduce demand is widely advocated. Examples from other utilities, and from the domestic/industrial sectors of water supply suggest the approach could be effective.

In developing countries, the facilities required for measured and controlled delivery of irrigation are rarely in place, and would require a massive investment in physical, legal and administrative infrastructure.

To be effective in curtailing demand, the marginal price of water must be significant. The price levels required to cover operation and maintenance (O&M) costs are too low to have a substantial impact on demand, much less to actually bring supply and demand into balance. On the other hand, the prices required to control demand are unlikely to be within the politically feasible range.

Furthermore, water *supplied* is a proper measure of service in domestic and industrial uses. But in irrigation, and especially as the water resource itself becomes constrained, water *consumption* is the appropriate unit for water accounting. This is exceptionally difficult to measure.

An alternative approach to cope with shortage would focus on assigning volumes to specific uses—effectively rationing water where demand exceeds supply. This approach has a number of potential benefits including simplicity, transparency, and the potential to tailor allocations specifically to hydrological situations, particularly where salinity is a problem.

Data from Iran are presented to support these contentions.

Charging for Irrigation Water: The Issues and Options, with a Case Study from Iran

C. J. Perry

Introduction

Until recently, water has been plentiful in most countries, and the role of water pricing as a means to ensure efficient allocation and productive use has attracted little attention.

Now, water is manifestly scarce in many countries (Gleick 1996; Postel 1996; Seckler et al. 1998); individuals, agencies and international declarations advise that water should be treated as an “economic good” (Briscoe 1996; Rosegrant and Binswanger 1994; ICWE 1992; Global Water Partnership 2000); in parallel with this development, the maintenance of water-related facilities is often observed to be inadequate (Jones 1995). These two issues together have provided an impetus for the introduction of various forms of pricing for water and water services. A primary target for these interventions is irrigation, because it is by far the largest consumer of water—typically 80 per cent—in most countries where shortage is a problem.

In this report, we first set out some basic issues related to the introduction of effective water pricing for irrigation services. We argue that implementation has a number of limitations in the irrigation sector, and that the scope for realizing benefits may be limited in relation to the physical, economic, financial and political issues of implementation. In the second part of the report, readily available data from Iran are used as a case study to support these contentions.

The Rationale for Water Pricing

In some irrigation projects water is provided as a free service. Elsewhere, even the low charges, supposed to be collected are, in fact, not collected (World Bank 1986). Where charges are low, or not collected at all, the direct beneficiaries of irrigation—who typically are a privileged group in most agrarian economies—receive their service at the expense of the economy in general,[1] as scarce public resources are used first to finance project construction and

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[1] Probably the most important benefit of irrigation is the overall reduction in food prices resulting from increased production. Thus the indirect beneficiaries of irrigation, the consumers of cheaper food, should be happy to subsidize irrigation development through taxes. Within irrigated agriculture, or within an individual project, however, the farmer who receives irrigation and benefits from it is clearly privileged in relation to a farmer who does not receive irrigation water, and a service charge may be appropriate to recover a proportion of the benefits or to cover the costs of the service.

then to subsidize ongoing O&M. All too frequently, the public subsidy is not forthcoming, the project deteriorates, productivity falls, and the scope for charging is reduced by the low quality of the service—a classic vicious circle of downward-spiraling performance.

Where charges are in place, the marginal price is often zero—for example, where the charge is fixed by crop or farm area, and does not vary with the quantity of water actually used. In this situation, even if the full costs of the service are recovered, there is no incentive for the farmers to save water—they will either take as much as they want while the (fixed) price allows a profit to be made, or not irrigate at all if they cannot make a profit.

Inter-sectoral water transfers (for example, reducing irrigation releases from a dam and allocating the water for domestic use) offer the appearance of greater simplicity and the possibility to use “bulk” prices, but additional difficulties arise here too. First, it is likely that the value of water in domestic, industrial, and commercial uses will be far higher than in agriculture. IWMI’s research (Molden et al. 1998) shows values of water consumed to be between \$0.03 and 0.90 per m^3. The value of water in nonagricultural uses is typically at least double the maximum agricultural value and, of course, the value of water for human consumption in times of extreme shortage is effectively infinite.

This leads analysts to believe that there is scope for enormous increases in economic benefit by market-based transfers of water from low-value agricultural use to high-value new uses in other sectors. The flaw in this argument, of course, is that once rather small volumes of water have been transferred to the high-value uses, the marginal value falls sharply into negative territory. The difference between dying of thirst and drowning is less than a tubful of water. And if inter-sectoral benefits of market transfers are to be realized, then the entire agriculture sector must be covered by infrastructure, and bureaucracy required for the measurement, billing, and transfer of water from the least-productive parts of agriculture to the more-productive areas. The potential costs and benefits for Egypt have been analyzed (Perry 1995), and the likelihood is that costs would substantially exceed the benefits.

It is clear from this brief introduction that there are a number of reasons, each with differing purposes, for recommending water charges. The three most common are

- to recover the cost of providing the service (either the full cost, including capital expenses, or the ongoing O&M cost, or some intermediate level)

- to provide an incentive for the efficient use of scarce water resources

- as a benefit tax on those receiving water services to provide potential resources for further investment to the benefit of others in society

Each of these three objectives requires specific levels and structures of pricing to be achieved. Here we concentrate on the first two—as a means of cost recovery, and a means of providing an incentive for efficient use.

Water Charges for Cost Recovery

Cost recovery requires a politically sensitive choice as to the extent of cost recovery—full recovery of capital and O&M costs at realistic interest rates, or partial recovery at subsidized rates.

The assessed total cost of water supply (and drainage) services must then be distributed among various beneficiaries—farmers, villages that receive domestic water supplies, flood control downstream, and sometimes hydropower. With this complex set of decisions made, a specific target revenue from irrigators can be defined. In fact, even this simple objective is rather complex in reality because the costs of O&M vary over time, especially when major replacement or modernization work becomes due, or when dealing with major events such as floods, which may damage infrastructure.

Thus even this simplest of charging structures will require political debate and decisions, planning, predictions, and financial management if a reasonably uniform pattern of charging is to be maintained. In the State of Victoria, Australia, irrigation systems are obliged to project expenditures over a 100-year period and adjust revenues to meet these with a stable revenue stream (Langford et al. 1999).

In the next section, attention is focused on the potential for using water prices to encourage efficient use, and on the level of charges required to achieve that goal. It is useful, first, to establish a benchmark of the level of charges that might be required to achieve recovery of the service costs. Data in this area are scarce, and we rely here on two studies that appear to be exceptionally comprehensive and credible. The first (ISPAN 1993) reviewed the situation in Egypt, and concluded that the full cost of irrigation and drainage O&M amounted to US$52/ha in 1995 US dollars. This equates to about $0.003 per m^3 of water delivered.

The second is a study prepared for the World Bank's appraisal of the Haryana Water Resources Project (1995). It found the cost of O&M to be $10/ha—again in 1995 US dollars—which amounts to $0.002 per m^3. These studies cover vastly different situations—Egypt having an intensively managed system, delivering large quantities of water to highly varied cropping patterns, with very extensive drainage facilities. Haryana's system is very water-short—availability is about one-third of that in Egypt, management is extensive rather than intensive, and drainage costs are minor. What the two systems have in common is that they are both successful and productive, and have been operating for many years.

Water Charges to Encourage Efficient Use

The second objective adds further challenges. To achieve an incentive for efficient water use, the price of water must be directly related to the volume delivered. Conceptually, this is identical to an electricity meter where the consumer can decide to switch off or switch on a particular device, and experience a directly proportional response in the electricity bill. Fortunately, electricity reacts instantly once the demand at the end of the wire is perceived, and the flow down the wire can vary sharply without operational consequence (except at the generator). The water flow is rather slow in canals, and must be issued well in advance of distant demands. Changes in demand during the period of distribution will result either in shortages—if demand increases unexpectedly—or in surpluses and spills if demand decreases.

We see already that transferring the electricity paradigm to water delivery has significant operational implications; if pricing of irrigation water is to be effective in reducing demand in surface irrigation systems, then specific and comprehensive *regulatory, operational* and *economic* criteria must all be met.

Regulatory Requirements

An orderly system of distributing water must be in place through some existing and respected regulatory framework for allocating water among farmers—rules and procedures defining rights and responsibilities; priorities in case of shortage or excess supplies; penalties for breach of rules, and so on. If this is not the case—or if regulations are not observed (if farmers take water at will, manipulate gate settings, tolerate significant interference in water, or do not pay assessed charges) then there is no immediate scope for improving water distribution through pricing, and attention should first be given to clarifying and enforcing water rights and the rules of water distribution. To then move on to volumetric supply, as required for volumetric pricing, additional procedures for both measurement of the quantity delivered, acceptable to the farmer and the billing agency, and accounting for partial deliveries, missed deliveries, excess deliveries, or late deliveries must be in place.

Operational Requirements

If pricing is to encourage changes in the pattern of demand at the level of the individual farm, then system operations must be such as to permit differentiated deliveries at this level. The operational implications of delivering and measuring a differentiated service at the level of the individual farm poses significant difficulties in many irrigation schemes, especially large surface systems (which comprise the major users of water). Such irrigation schemes comprise hundreds, if not thousands or even millions of individual consumers.

Measurement and charging at the farm level will require substantial investments in equipment, and an associated administrative bureaucracy to collect and collate data on farm-level deliveries, and undertake the billing process.

We recognize that there are procedures and technical approaches to resolve this problem. The approach has proved feasible in countries such as Australia and the USA, but it is important to recognize that farm sizes in both these countries are typically 10 to 100 times larger than those in many developing countries. This directly indicates the associated additional complexities of billing and also the far greater hydraulic complexities of delivering (or not delivering) incremental water supplies to individual farmers. The hydraulic complexity results from the fact that changes in flow rates at one point in an open surface system generate impacts on all downstream flows, which can be dealt with, but using rather different infrastructure than most systems now have. In Israel, while farm sizes are often comparable to those in developing countries, the infrastructure is mostly such as to allow precise and verifiable delivery of water to individual farms—and the concept of scarcity was dominant in the original system design rather than emerging over time (as is the case in many existing systems). We see very few large-scale irrigation systems in developing countries where the providing of infrastructure for such service would not involve effectively reconstructing the system.

An alternative approach in the context of developing countries, to avoid the “small farm” problem, is to deliver water to an intermediate point—a farmer organization, a lateral, or a village—on the basis of volumetric pricing, and allow the farmers to distribute the water "internally." This has the attraction, from the agency's viewpoint, of devolving the most difficult part of the operation (the actual interface between "supply" and "demand") to others—a common feature in many participatory management approaches. But the overall management task of delivering differentiated supplies to individual farms remains, as indeed does the required regulatory framework, the need to measure and bill, and so on. If these aspects are missing then the direct link between service and payment is lost, and the efficiency incentive that pricing is designed to produce is neutralized.

Economic Requirements

If the charging system is to have an impact on consumption, then the system of payment must be such as to induce the desired economic response. We can usefully distinguish between two desired responses; the first is simply to make the user aware of an incremental charge related to incremental use, and to encourage avoidance of waste. This is analogous to the small cost incurred in leaving a light on—we are conscious of it, we will tend to avoid leaving lights on for long periods during daylight hours, but may leave lights on at night for the convenience of finding a stairway well lit rather than having to seek the switch in the dark.

The second objective of marginal pricing is actually to achieve a balance between supply and demand through the pricing mechanism—in other words, to find that price that will optimize demand for and allocation of any given availability of water. This, of course, is a far more complex pricing objective because the value of water varies very sharply by crop, by stage of growth, and by soil type, and most difficult of all, depending on whether it has rained, is raining, or will rain soon.

Which objective of pricing is sought—to *balance supply and demand* or simply to *reduce demand*—must be very clearly understood in the process of designing a pricing system.

If the objective of marginal water pricing is to balance supply and demand, then the price charged must be significant in relation to the benefits derived from using water. As noted above, IWMI's research has shown that the value of water consumed in agriculture ranges from $0.05 to 0.90 per m^3, with the great majority of observations falling in the order of $0.10–0.20 per m^3. We can assume, on this basis, that prices of less than a few cents per cubic meter will have little effect on demand. Indeed, research has shown in the case of Egypt (Perry 1995) that the price required to induce a 15 percent fall in demand for water would have reduced farm incomes by 25 percent.

If the objective is simply to reduce demand to some unspecified degree, then two further issues must be considered: first, it will be necessary to have additional quantitative controls on supply (because the proposed price will not achieve the necessary balance); and second, the question of the balance between the cost incurred to induce the intermediate fall in demand and the actual water "saved" should be considered. In this case, the water saved through pricing is zero (because the level of consumption is determined by the quantitative controls, which would work perfectly well in the absence of pricing).

The Issue of "Saving" Water

One final problem plagues the achievement of efficiency benefits through irrigation water pricing, even if infrastructural, operational, political and bureaucratic hurdles can be crossed. This issue concerns the nature of "efficiency" in water resource systems.

In the municipal and industrial sectors of water supply, the agency providing the service appropriately considers the volume and quality of water delivered as measures of service. This is appropriate because the agency will have paid to capture the water, treat it to meet specified standards, and deliver the water through its distribution network. Reductions in demand from users will save the agency money on each of these activities. Also if users waste water by taking more than they need to fulfill a particular objective, the agency (or another agency downstream) would again have to capture, treat, and distribute this water—incurring further costs.

But when basin-level *resource* scarcity becomes the framework for analysis (rather than sector-specific *cost* accounting) the picture changes dramatically: we must focus not on water diversions, but on consumption, and recognize that where "wasted" water is recaptured downstream, the resource cost of the "wastage" is essentially zero unless substantial pollution has occurred in the recycling process. An approach to addressing "efficiency" and salt pollution has been suggested elsewhere (Keller and Keller 1995). In the context of overall water shortage it is not diversion, but consumption—through evapotranspiration, pollution, or loss—which is the concern.

We have already argued that it is difficult to envisage a system of accurate measurement of deliveries to farms in large-scale irrigation systems in developing countries. The measurement of consumption is inherently much more complex because it involves spatially distributed return flows to drains, rises and falls in local water tables, rainfall, and so on.

In some cases, moreover, excess water delivered during one season recharges an aquifer, which provides water in a subsequent dry season when there may be no alternative supplies, and indeed the water is considerably more productive. Such situations are common: in parts of China, India and Pakistan, the area irrigated by wells is comparable to (and in some areas, more than) the area irrigated by surface supplies—but many of these wells are in surface-irrigated commands and thus depend substantially on recharge from surface "losses." In all heavily developed basins, with more than one diversion point on the river, a proportion of the "losses" from upstream projects forms inflows to downstream projects.

In any of these circumstances, an increase in "efficiency" will reduce the flows to the aquifer, drain, or river, by roughly the same amount as "losses" have been reduced. This is entirely desirable where the aquifer is saline, or so deep as to be beyond economic recovery, or where drainage flows cannot be recaptured for downstream use. In some cases, the effective loss in terms of productive potential may sometimes, on further examination, turn out to be far greater than initially estimated when excess water picks up local salt from the soil and returns this extra polluting load to the river—reducing potential productivity downstream.

We believe that this complex situation makes it virtually impossible to formulate a pricing structure that can serve the multiple objectives of water charges, and the various hydrological situations where it may be desirable to decrease, stabilize, or increase the water supplied to irrigation systems. Certainly charging for water can give incentives, but broader objectives of balancing supply and demand or stabilizing environmental impacts are unrealistic. Even the introduction of incentives will require massive improvement in the infrastructure, management and regulatory framework that characterizes most irrigation systems.

A Case Study: The Zayandeh Rud Basin, Esfahan Province, Iran

The Zayandeh Rud basin (figure 1) has an area of about 4 million hectares, of which 8 percent (300,000 ha) is irrigated—about 3 percent (130,000 ha) under surface irrigation in large, government-constructed schemes drawing from the Zayandeh river, and the rest in small groundwater or kanat-supplied areas that are privately owned and operated.

Annual rainfall in the irrigated areas is 100–200 mm and annual ET is in the range of 1,500–2,000 mm, so irrigation is essential for agriculture. Presently available surface water resources from the Zayandeh river, augmented by interbasin transfers, total 14 billion m^3. These resources are essentially fully consumed by the existing facilities, and residual flows reaching the Gavkhuny marsh are limited in quantity, and of unusable quality. With the exception of small areas with positive recharge from nearby hills, the groundwater balance is marginal, and in some areas consumption exceeds recharge.

The Zayandeh Rud basin is thus extremely short of water, and the distribution of available supplies is unequal in terms of both quantity and quality. Projects drawing from the river in the upper reaches are relatively plentifully supplied with good quality water; rice is a common crop and irrigation intensities are high. Moving downstream, irrigation supplies decline both in quantity and quality until the lower reaches where the quality of water from the river becomes marginal—and eventually unusable. Farmers supplement deliveries by pumping from groundwater and drains, wherever such water is fit for use, and in some cases by using water of extremely poor quality.

Water Charges and Water Consumption

As outlined above, to assess the potential impact of pricing water, a number of issues must be addressed:

- the nature and extent of water “losses” and potential savings
- the cost of “saving” water and the cost of surface supplies
- the cost of water and its value to farmers
- the impact of charges on water demand
- salinity and salinization

This disaggregation is attempted below.

The Nature and Extent of Water “Losses” and Potential Savings

How much water can reach and be consumed by the crops out of what has been stored, diverted, conveyed, delivered and applied to the field is central to project planning, and the day-to-day operation of irrigation systems. “Losses” in this process—the quantities of water released from storage that do not reach the crop—are the legitimate concern of the operators and beneficiaries.

FIGURE 1.

The Zayandeh Rud basin.

But two separate and often coexistent features dramatically alter the appropriate perspective once resource planning (rather than project planning, or local management) is the objective. These features are reuse of “losses,” and basin-level competition.

Commonly, for surface irrigation schemes such as those found in Iran (Bybordi 1989), the ratio of water delivered to the project to the water consumed by crops is about three to one—that is, for every 3 m^3 delivered at the head of an irrigation system, only 1 m^3 is transpired by the crop. In such a case, the “efficiency” would be calculated as 33 percent, and 67 percent would be assumed to be “lost.”

Reuse of losses occurs most commonly when

- seepage from canals and fields reaches aquifers that can be exploited

- farmers recover water from local drains

- the outflow from drains flows to a river that has downstream diversion works

However, a critical examination of local conditions may show that the potential to recover such “losses” is limited by existing recycling—which may be active (wells; pumping from drains) or passive (drains flowing to the river and on to downstream diversions; capillary rise from shallow water tables to support crops)—in other words, the losses are already being recovered!

The Cost of "Saving" Water and the Cost of Surface Supplies–Incentives at the Farm Level

Water delivered to the farmer goes to one of three uses: it is utilized by the crop, runs off the field into a drain, or percolates to the water table. The farmer benefits from the first of these uses, and may suffer—through waterlogging or leaching of nutrients—from the other two.

If the price of water delivered to the farm is increased, the farmer will have an incentive to reduce his or her demand for water by reducing the water going to the drains and to the aquifer.

First, it is important to note that the farmer's incentive to reduce losses is linked *only* to those losses that are within his or her control while overall irrigation system losses may amount to 60–70 percent. In Iran as elsewhere, typically less than half of these occurs at farm level, the rest being operational losses, and seepage from main and distributary canals. Thus the farm-level losses may amount to 30 percent of the water supplied to the project—*even less if some of this excess delivery is recovered for further use*.

Table 1 calculates the cost per m^3 of reducing required water deliveries by investing in improved irrigation technology at $1,000 per ha—a typical figure in Iran for the installation of sprinkler systems. The cost per m^3 saved is shown in the second column ($0.11 per m^3 for year-round, and $0.14 per m^3 for single-season irrigation), based on the assumptions about Crop Demand, Losses, and Costs detailed in the columns to the right.

Year-round irrigation has a higher total cost of operation ($348 compared to $220), but lower cost per unit of water saved (about $0.11 per m^3 compared to 0.14 per m^3) because the fixed costs are distributed over a larger number of units. For both situations (year-round and single-season, the sensitivity of the cost of water saved is tested by increasing and decreasing each parameter by 20 percent. For example, if the losses before the improvement are 20 percent higher (i.e., 36%) in the single-season situation then the cost of water saved falls to $0.10 per m^3; while if the losses are lower by 20 percent, then the cost of water saved increases to $0.21 per m^3.

The calculations indicate that the cost to the farmer of water saved through improved on-farm technology will be in the range of $0.08–0.21 per m^3 depending on the total volume delivered and the costs of investment and operation.

Taking the minimum cost ($0.08 per m^3), which applies for the case of maximum water deliveries, it is interesting to compare this to the current price of irrigation water, which is 20 Rial per m^3, or $0.004 per m^3. If volumetric prices are to be used to induce farmers to invest in improved on-farm technology to save water, then water charges would have to exceed $0.08 per m^3—a 20-fold increase—for the investment in on-farm water management to be profitable. This, in turn, would result in water charges of about $400 per ha for a crop such as wheat (with current yields of around 5 t per ha and a price of $120 per t, water charges would account for two-thirds of gross revenues).

These calculations indicate that for basic field crops, the cost of saving water through investment in improved irrigation technology is unattractive, and the cost of surface water would have to be increased enormously to make such investment an attractive alternative to purchasing additional water from a volumetrically priced surface source.

TABLE 1.

Cost of reducing water deliveries by improved irrigation technology.

	Cost of water ($/m^3)	Crop demand (m^3/ha)	Losses before (%)	Losses after (%)	Reduced delivery (m^3/ha)	Capital cost ($/ha)	Interest %	Life (years)	Capital cost/yr. ($)	Operational cost ($/ha/yr.)	Total cost ($/ha/yr.)
Two season	0.11	10,000	30	10	3,175	1,000	10	10	148	200	348
Cost/m^3 for...											
+20%		9	8	12		12	11	11		14	
-20%		14	17	10		10	11	12		8	
Single season	0.14	5,000	30	10	1,587	1,000	10	15	120	100	220
Cost/m^3 for ...											
+20%		12	10	15		15	15	13		16	
-20%		17	21	13		12	14	15		13	

TABLE 2.

Gross and net values of production for major crops.

Crop	Land preparation seed (R/ha)	Irrigation pesticides (R/ha)	Harvest costs (R/ha)	Total costs (R/ha)	Yield (t/ha)	Price (R/ton)	Gross value of production (R/ha)	Gross value of production ($/ha)	Net value of production (R/ha)	Net value of production ($/ha)
Wheat	350,000	500,000	150,000	1,000,000	6.5	650,000	4,225,000	704	3,225,000	538
Barley	350,000	350,000	150,000	850,000	6.0	500,000	3,000,000	500	2,150,000	358
Maize	350,000	500,000	200,000	1,050,000	6.0	500,000	3,000,000	500	1,950,000	325
Rice	2,500,000	500,000	1,000,000	4,000,000	5.5	1,750,000	9,625,000	1,604	5,625,000	938

Note: R = Iranian Rial. US$1.00 = R6,000 (in 1993).

The Cost of Water and Its Value to Farmers

The value of water to farmers is an extremely complex issue. The *marginal* value of water varies sharply through the season—water to complete the development and harvest of a nearly mature, high-value crop will have a very high value; additional water after an irrigation, or rainfall may have a negative value.

The *average* value of water (value of crop divided by total water used) is more stable, and is a useful indicator of the general value of water to farmers. Even here there are many complexities:

- The net value of the crop depends on valuation of the crop itself and cash inputs, any or all of which can be significantly distorted by market imperfections or taxes/ subsidies.
- The valuation of noncash inputs such as land, family labor and draft animals, is extremely difficult.
- The basis for computing water consumption may be water diverted to the project; water applied to the field; or water actually consumed by the crop (values that, as indicated above, may vary by a factor of three).

Table 2 summarizes data from Esfahan on typical yields of major crops. Gross values of production range from about $400 to about $1,600, while net values are generally some 30 percent lower.

IWMI has made extensive studies of the gross value of water per unit of water applied and per unit of water diverted and consumed. These values range from $0.03 per m^3 for rice (water applied) to $0.50 per m^3 (water consumed) for vegetables and fruits. Typical gross values per unit of water consumed range from $0.10 per m^3 to $0.20 per m^3, and these values compare well with data from Zayandeh Rud for a range of crops, as shown in table 3, which is based on the crop budgets from table 2, and the calculated water requirements for the area. (IWMI uses international prices to value crops; here, local prices have been used, which appear to be somewhat below world prices).

The values calculated are well within the range of other values obtained in IWMI's studies, and are consistent with the observed trends elsewhere. Rice, for example, shows poor returns per unit of water delivered due to the high requirements for field preparation and percolation, but high values per unit of water consumed (emphasizing how essential it is to evaluate "losses" in assessing the desirability of rice cropping).

Present water charges, applied volumetrically at the current rate of Rial 20 per m^3, would amount to $30–40 for wheat, barley and maize, and $90 for rice. In each case, this value is about 5 percent of total revenue, and less than 10 percent of net revenues—significant, but small in relation to the overall crop budget.

The Impact of Charges on Water Demand

These values provide a useful guide to evaluate the importance of water charges at present, the attractiveness of new technologies, the incentives facing the farmer, and the implications for water use.

To simplify the discussion, we focus on typical values, rather than the ranges and extremes, which have been calculated above. We assume that

- the present price of water is $0.004 per m^3
- the cost of reducing water deliveries through improved technology is $0.10 per m^3

TABLE 3.

Value of water for major crops.

Crop	Gross value of production ($/ha)	Net value of production ($/ha)	Total irrigation delivered (m^3/ha)	Net water consumed (m^3/ha)	Gross value (¢/m^3)		Gross value ($/$m^3$)	
					delivered	consumed	delivered	consumed
Wheat	704	538	8,286	6,800	0.085	0.104	0.065	0.079
Barley	500	358	8,286	6,800	0.060	0.074	0.043	0.053
Maize	500	325	11,214	7,900	0.045	0.063	0.029	0.041
Rice	1,604	938	21,714	9,200	0.074	0.173	0.043	0.102

Note: The water delivered is calculated as: (ET - Effective rainfall)/70 percent for maize, wheat and barley, and (ET - Effective rainfall + land preparation and percolation)/70 percent for rice. The ratio of 70 percent accounts for farm-level efficiency. This is the relevant figure, as investments in on-farm improvements can only effect efficiency at this level.

- the net value of water delivered to farmers is \$0.05 per m^3
- the net value of water consumed by the crop is \$0.08 per m^3

The first two values indicate that volumetric pricing in any form, in the absence of much higher water charges, will have very little impact on farmers' choice of crop or choice of irrigation technology.

More detailed consideration of the last two values provides important insights into what can happen if water charges are substantially raised, or if water allocations to farms are physically limited below potential demand (for example, if water deliveries were restricted to 15,000 m^3 per ha in rice areas, or 5,000 m^3 per ha in non-rice areas).

Note that the value of water *consumed* is comparable to the cost of reducing deliveries through improved technology. Put another way, if the farmers switch to (say) drip irrigation, and avoid the flows to drains and groundwater that currently occur, they can *consume* a higher proportion of the water delivered to his farm. Each farmer's benefit is \$0.08 per m^3 at present levels of productivity, and the cost to each is \$0.10 per m^3. But conversion to drip or sprinkler may also be accompanied by higher yields (better water control) and perhaps a shift to higher-value crops such as fruits and vegetables.

The impact of this would be a desirable *increase* in productivity of land, an *increase* in the volume of water *consumed* at the farm level, and a *decrease* in return flows to drains and aquifers. The latter points are crucial. Improved crop growth and yield are almost invariably associated with an increase in transpiration, so we can be quite sure that one of the "uses" of water will increase. If the return flows were not recoverable, the implications for downstream users of the increase in transpiration will be neutral—deliveries to the upstream area were in any case a reduction in flows available to the downstream users. If, however, the return flows were recoverable downstream, the new situation is that upstream consumption increases, return flows *decrease*, and downstream users experience reduced availability of water as a result of improved upstream "efficiency"!

Of course, the new situation offers the possibility of reducing deliveries to the upstream users (who are now getting increased production by "capturing" more beneficial use of the water delivered to their farms). The question then arises as to whether upstream users will wish to invest in improved technology if their water allocation is in consequence reduced, and the savings from their investments are passed to others.

The Issue of Salt

The water in the Zayandeh river contains a natural salt load. As the water is diverted for irrigation, and any excess water returns to the river, the downstream salt load increases, reduces, or stays constant, as described below. Whether changes in the salt load are desirable or not depends on local and basin-level objectives. In considering this issue it is essential to distinguish between the salt *load*, and the salt *concentration* at any given point of measurement.

Suppose the annual water supply released from the dam for downstream use is 100 million cubic meters (Mm^3), and the salt concentration is 500 ppm. Then the total salt load delivered from the dam is 50,000 t per yr., and the first downstream irrigation project diverts 50 Mm^3.

Case 1

If 80 percent of the diverted water is consumed by crops, and the unconsumed water is just sufficient to carry out all the incoming salt to the river in the return flow, then:

- The downstream flow is 60 Mm^3.
- The downstream concentration is increased to 833 ppm.
- The downstream salt load is 50,000 t per yr.
- No salt is accumulating in the irrigated area.

Case 2

If the entire volume of water is consumed by irrigation, so that there are no return flows to the river, then

- The downstream flow is 50 Mm^3 per yr.
- The downstream concentration is unchanged at 500 ppm.
- The downstream salt load is 25,000 t per yr.
- In this area, 25,000 t per yr. of salt are accumulating.

Case 3

As in Case 1, except that the soils in the irrigated area are saline, and the return flows pick up a further amount of salt equal to that delivered in the incoming irrigation water:

- The downstream flow is 60 Mm^3.
- The downstream concentration is increased to 1,250 ppm.
- The downstream salt load is 75,000 t per yr.
- From the project area 25,000 t per yr. of salt are being removed.

There are, of course, an infinite variety of such possibilities, and there is likely to be variation *within* individual projects. Further, these scenarios change over time; land that is irrigated for the first time may often correspond to Case 3, but over time, as the salt is leached from the profile, it moves towards Case 1.

These alternative local scenarios and downstream impacts have implications for government objectives in water management, and the impact of farmers' efforts in response to water charges or changed technology.

In Case 1, the local area is kept salt-free, and the salt load in the river is constant, to the detriment of downstream users. Case 2 represents the case of more "efficient" irrigation, and leaves the downstream water quality unchanged, but threatens the sustainability of irrigation in the hypothetical upstream project as salt builds up in the area. Case 3 is the reverse—the upstream area is improving while the salt load downstream is sharply increased. It is clear from these examples that irrigation “efficiency” and productive, sustainable irrigation have no precise relationship, and that the optimum “efficiency” must be locally defined in relation to impacts in the area concerned and elsewhere. The implications for a pricing policy as a tool in this environment are obscure.

An Alternative Approach to Improving Productivity

It is striking that many of the issues identified above must be analyzed in terms of volumes of water. The water available is a volume, and how it is used (through crop ET, to groundwater, to drains) are all volumes, and the salt balance is based on water and salt volumes and their spatial and temporal distribution.

It is also *relatively* easy to define sustainable irrigation in terms of the water that should be applied, water that should (or should not) return to the system, and water that should go to groundwater to maintain sustainable balances in each area. It is also easiest to define the political economy of water in terms of allocations of water to areas, groups, or individuals.

And finally, it is important to note that the incentives to utilize water productively are made clear to the farmer just as directly by rationing water as by trying to establish an appropriate system of water charges. In northwest India, the long-tested *warabandi* irrigation system (Malhotra 1982) is based entirely on ensuring an equitable distribution (over the land) of limited water resources. Water charges are not high, and not volumetric, but because all farmers are water-short, they experiences directly the true value of their water ration, and strive to save every drop and maximize its productivity.

Conclusions

The apparent misuse and waste of irrigation water, especially in the context of low and subsidized prices for water and deterioration of irrigation systems, suggest that charges should be increased to cover the costs of system operation, and that pricing mechanisms should have a prominent role in encouraging more efficient resource use.

The analysis above and data from other countries suggest that the likely charge needed to cover O&M costs would be \$0.003–0.005 per m^3, while the charge required to substantially affect demand would be much higher—perhaps \$0.02–0.05 per m^3. This indicates that a charge designed to meet the cost recovery objective will have minimal efficiency impact and that a charge that meets the efficiency objective will recover far more than the costs of O&M, which seems attractive.

However, water is a complicated natural resource:

- It is difficult to allocate and measure, especially in large surface systems with many small farmers—indeed it is rare to find even simple proportional allocations being achieved, with head-end farmers (and projects) usually getting more water than tail enders.

- The nature and extent of actual losses are rarely easy to assess, due to reuse and recycling locally and downstream. The extent to which “savings” will be achieved through water charges or changes in technology can only be assessed through a full accounting of water flows in the basin.

- The salt load that is found in every basin complicates the analysis of water distribution and consumption considerably, due to conflicts between “on-site” objectives of avoiding the accumulation of salt, and downstream impacts of concentrated salt loads.

Water is also a complicated economic resource:

- Its value varies sharply across time, space and use.

- Its value in irrigation is generally a large multiple of its cost, but the cost of “saving” water as a source of extra water is very expensive.

And water is a complicated political resource:

- Farmers are often an important political constituency, and strongly resist increases in the price of irrigation services.

- The level of price increases that would be required to have a significant impact on demand (for example, by a factor of 5–10) would be politically very difficult to enforce.

- The level of water prices that would induce changes in demand would result in substantial profits to the supplying agency, which would present a further political difficulty.

In sum, introducing volumetric water charges is difficult and unlikely to result in water savings within the politically feasible range of prices—and introducing charges at a lower rate will have no impact on demand, but will significantly increase the costs of irrigation services. And the “correct” price structure to balance supply and demand will not be the “correct” price structure required to meet environmental needs, and also will not be the “correct” price to meet socio-political needs.

Many of the assumed advantages of water pricing can be achieved through physical rationing of water, which is also easier to implement and administer, more transparent, and more readily adjusted to meet local considerations such as rising or falling groundwater conditions and salt management. For Iran, as in many other countries, uniform water allocations per hectare would achieve some very important steps in the reallocation of water from overusing upstream areas, where groundwater is also relatively fresh and abundant, to the water-short and salt-abundant downstream area. Such an approach would also be politically easier to explain than resorting to water charges, especially (as is all too likely) if charges are set well below “value” so that a) farmers upstream will buy even more than they now get and b) they will have no incentive to invest in *productivity*-enhancing technologies.

This suggests that it may be more productive (at least in the short run) to set water charges so as to ensure financial sustainability of the irrigation systems—that is, to recover full O&M costs. The objective of increased water use efficiency will be better served by volumetric allocation of water rather than expecting markets to achieve the desired balance among competing objectives in production, environment, and social equity.

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