IRRIGATION WATER MANAGEMENT POLICIES:

ALLOCATION AND PRICING PRINCIPLES AND IMPLEMENTATION EXPERIENCES[1]

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Abstract

Food security and sustainable development requires efficient use of water resources, especially in irrigation. Economic pricing can be an effective tool to achieve more efficient water use, provided it is supported by other policies in implementation. Applying various water pricing and cost recovery arrangements is suggested for efficient allocation. Any adverse impact on farmers' incomes must be addressed and higher prices linked to more reliable service. Experiences among several countries suggest a variety of implementation issues. Where farmers switch to high-value water-intensive crops following a rise in price of irrigation water, it may be necessary to raise prices even further to discourage that practice. Essential complements to water pricing are water distribution rules and technological choices at critical nodes in the delivery system that allow farmers flexibility in conserving water in response to higher prices. Among other supporting institutions, water users associations seem a higher priority than water markets.

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Recent projections by several international agencies (Tiwari and Dinar, 2002) imply that global food security will be greatly strengthened if scarce irrigation water is carefully managed. There is evidence that water world wide is not used efficiently. There is also evidence, that, among other measures, properly implemented economic incentives have resulted in improved Water Use Efficiency (WUE) in irrigation and in less waste in urban water deliveries.[2] We also observe several policy interventions that enhance efficient water use, such as right-based water allocation, customary use, self-supply, water pricing, informal and temporary water markets, etc… This paper considers the possibilities of pricing and other complementary strategies in achieving efficiency of water use. The paper notes, in particular, that while pricing may be a useful tool, it is not always easy to implement and raising prices can sometimes have the effect of increasing overall water use. This could happen particularly where prices of agricultural products are set by governments to achieve non-economic objectives. Two policy interventions are associated with charging for irrigation water. The paper finds that, in general, the importance of financial cost recovery for irrigation provision is gaining greater acceptance than economic pricing. Further cost recovery through pricing strategies will require technological and institutional modifications that help farmers gain greater control over their water usage. At the same time, since raising irrigation water prices can hurt farm incomes and employment, efforts to gain farmer acceptance during the adjustment period will be crucial.

The paper is based on a subset of works presented at the international conference “Irrigation Water Policies: Micro and Macro Considerations, Agadir Morocco, June 15-17, 2002”. The papers are accessible on the web. All monetary values in this paper are taken

[2] The term water use efficiency has several definitions. The authors of the various presentations that are summarized in this paper do not always define which ‘efficiency’ they are referring to. Therefore, the definition of the various efficiencies used will remain vague. Please see Annex 1 for more explanation.

from the original papers. Conversion factors and year of reference to the local currency can be found in the original papers in http://www.worldbank.org/agadirconference.

The paper is organized as follows. In the first section, recent projections of food security and the role of irrigation in achieving such security are discussed. This is followed in the second section by an outline of pricing principles that relies on traditional economic foundations but also considers the importance of water as a basic good. The third section then considers several studies that examine the impact of raising water prices on the efficiency of water use in particular activities and also on the overall demand for water as cropping patterns shift in response to price changes. The fourth section documents the importance being accorded to the principle of cost recovery and draws several lessons from experiences across a large number of countries. The fifth section then considers the pragmatic implementation of pricing policies, focusing on the role of technological innovations and supporting institutions, on the importance and mechanism of gaining farmer acceptance for raising prices, and on the role of water markets. A brief conclusion brings together the main findings.

II. Irrigation and Global Food Security

Fears about declining arable land and water resources to feed a growing population have been allayed by both the FAO (Faures et al.) and IFPRI (Rosegrant and Cai) in their forecasts for food security and irrigation water demand. Their conclusions however, derive from different perspectives. FAO's approach reflects on the most likely future scenarios rather than most desirable ones. The FAO's conclusions rely on declining growth in the demand for food grains on account of a declining population growth rate and the possibilities for continued expansion of irrigated area. In contrast, IFPRI projects that if water prices are raised, then a significant increase in water use efficiency is possible in non-agricultural sectors compared with irrigation, releasing water for more effective irrigation and thus allowing expansion of food production. At the same time, the IFPRI study also concludes that reduced withdrawal and depletion of water will serve to maintain irrigation system reliability and protect the environment.

Crucial to the forecasts for food security is the demand for and availability of irrigation water for irrigation. FAO statistics report that although irrigated agriculture constitutes only 20 percent of all arable land in developing countries, it accounts for 40 percent of all crop production and almost 60 percent of cereal production (Burke). Irrigated agriculture has a vital role in facilitating high cropping intensities and yields necessary for maintaining global food security. This has been the case over the past decades and will continue to be so in the foreseeable future. While FAO data underscores the importance of irrigated agriculture for food security and highlights the demand for water, IFPRI's analyses draw attention to diminishing access to water resources, by 2025. They find that under assumptions of low-investment in irrigation, high inter-sectoral water demand, and restricted ground water pumping, irrigated harvested area will decline due to reduction in water available for irrigation. Further, under the more water-scarce scenarios, the amount of water available per hectare of irrigated area will also decrease (The World Bank). However, according to IFPRI's revised scenarios as conveyed in the forthcoming World Bank report, a high increase in rain-fed area and improvement in water harvesting techniques and crop yields could potentially compensate any loss in food production.

In projecting demand for irrigation in 2015 and 2030, the FAO study concludes that irrigation water withdrawals will grow by a modest 14 percent between 1997/99 and 2030, accounting for only 8 percent of the renewable water resources of the 93 developing countries studied, and will be sufficient to ensure food security at the global level. The data shows that irrigated area is expected to grow to 242 million hectares by 2030 from 202 million hectares in the base period, 1997/99. Most of the increase in irrigation will occur in South and East Asia where arable land is scarce. However, greater efficiency in irrigation water use will play an essential role because of increasing pressure on scarce water resources from other competing sectors.[3]

Rosegrant and Cai's analysis also takes into account other sectors competing for scarce water resources instead of focusing attention primarily on crop yields. Their model allocates available water to different sectors with domestic demand receiving top priority

[3] Net irrigation water requirement is the difference between calculated evapotranspiration of the irrigated area and actual evapotranspiration under non-irrigated conditions. The ratio between the estimated irrigation water requirements and the actual irrigation water withdrawal is irrigation efficiency. Countries with abundant water resources, such as Latin America, have lower efficiencies of 25 percent while water scarce areas in Near East/North Africa and South Asia have efficiencies of 40 percent and 44 percent respectively. Also, efficiencies are expected to increase by only 0 to 4 percentage points in Latin America and sub-Saharan Africa but by 13 percentage points in Near East/North Africa.

and irrigation being given the residual amount. The impact of increasing water prices for industrial, domestic, and agricultural uses on the environment and food security is also examined. Beginning with Business as Usual (BAU) as the baseline scenario, six combinations of basin efficiency and allocation of water for environmental uses are subsequently assumed to analyze higher price situations.

Under the BAU water price situation, growth in irrigated area will be modest because of water supply constraints. Most of this expansion will be in Asia, especially in India and China. IFPRI's study focuses attention on the need to improve basin efficiency in order to maintain irrigation water supply reliability at the level in the baseline (BAU) scenario. Further, under assumptions of higher prices for water in non-irrigation sectors and higher basin efficiencies, levels of water withdrawal and water depletion from renewable water are significantly lower in 2025 than under the baseline scenario. Globally, the ratio of water withdrawal to total renewable water is 8 percent compared to 10 percent under the BAU scenario. More than 20 percent reduction is expected in China, Southeast Asia, Latin America, West Asia, and North Africa.

Both studies emphasize that higher levels of water use efficiency in agriculture can potentially balance demand for and supply of water to the sector. The IFPRI study also suggests that large increases in water prices can induce increased water use efficiency without adversely affecting food production. Developing countries are expected to become net cereal importers with water use efficiency at the BAU levels and net exporters at higher efficiency levels.

Based on panel data for 65 countries in Asia, Africa and Latin America from 1972 to 1991, Bhattarai's analysis has elements of both the FAO and IFPRI analysis, but applied to different groups of countries. He finds a non-linear relationship between irrigation and societal income level. When incomes rise from relatively low levels, irrigation requirements expand relatively rapidly. This implies irrigation would need to expand in South Asia, Near East, and North Africa, all of which are water scarce areas. However, with improved technology and changed resource allocation decisions, higher income countries can be expected to limit demand for irrigation water through more efficient water use. The findings suggest that expansion in irrigated area is more likely to occur in the earlier stages of economic development and slow down later as efficiency enhancing improvements are possible. The implication of the IFPRI analysis, however, is that even in low- and middle-income countries, efficient water use in irrigation can be achieved through the pricing mechanism.

In summary it appears that a global supply-demand balance for food is feasible for the next 25 to 30 years. However, the studies also suggest that improved efficiency of water use will be important in achieving this balance. This will be particularly so in areas that are water scarce and where population growth rates are relatively high. As such, a central question for policy makers is how to achieve this greater efficiency. In the following sections we discuss the options and empirical evidence on pricing and other measures to improve efficiency of water use in irrigation.

III. Principles for Pricing Water

Traditionally, extraction of water from rivers and deep wells, treatment, and delivery to a wide array of users has been entrusted almost entirely to governments. However, such centralized management of water is regarded today as having failed to serve the needs of the consumers, especially in developing countries. On the one hand, water has been supplied either free of or at very low charge to farmers, while on the other, huge revenue shortfalls have resulted in poorly-maintained supply systems that are unable to provide reliable service.

Some authors take the view that water has several non-economic characteristics, which require to be taken into account when making water policy (Hellegers, Hamdy and Lacirignola). While that is a legitimate concern, others argue that even so the economic principles of marginal and average cost pricing can be used to establish some pricing benchmarks. In addition, where broader environmental and public resource use concerns are important their value can also be incorporated in pricing benchmarks. Complementing these pricing strategies other demand management techniques can also be deployed effectively.

The question arises: at what level then should the user be charged and what blend of policies is needed to realize water savings? While “full cost recovery (FCR)” is desirable from the point of view of long-term ability to finance irrigation, equity and problems related to practical implementation need to be assessed. With regard to equity, if water is to be regarded as a basic need, and certain segments are unable to afford priced water, any adverse impact of a full cost pricing policy on income distribution has to be considered (see, for example, Hamdy and Lacirignola).

The challenge in pricing water is to identify the right balance between treating it as an economic good, i.e., a scarce resource that has to be allocated among various uses, and as a social good, "whose availability to certain groups and for certain purposes will serve the greater benefit of society as a whole (Hellegers, p. 4)". Abu-Zeid points out that the value of water is different to different groups. Viewed as a pure private good, the poor would get far less water than the rich even if the marginal value to the poor was much higher than other values, simply because it is unaffordable. As a public good, it is a basic human need and some reasonable amount should be available to everyone. To environmentalists, the transfer of water to irrigation may cause problems of salinity, chemical pollution of aquifers and resettlement of people from the areas submerged by reservoirs. Thus, irrigation water constitutes a transfer from ecological functions and since it lowers food prices for all, the public should share in the costs of developing and sustaining water systems. At the same time, Perry notes that externalities in terms of return flows must be taken into account and, as such, a pricing strategy ought to allow for the requirements of the water basin and not just of individual farmers or production and consumption sectors.[4]

Recognizing that irrigation water faces high opportunity costs while the ability to pay by users is very low, Hellegers argues that economic efficiency[5] is only one criterion for making socio-economic trade-off analysis. Equally important are criteria for social equity[6] and ecological sustainability when determining optimal allocation of a scarce resource with a high social value. Such criteria, if incorporated in the analysis could lead to socially efficient allocation. Hamdy and Lacirignola assert that the provision of water cannot be left entirely to free market forces because its basic needs dimension must be recognized and vulnerable social groups must be protected. Governments subsidize irrigation because it is

[4] Only about 30 percent of the water delivered to a farmer is used by him; the rest is either lost through evaporation or seepage that returns to the water system.

[5] Economic efficiency is achieved when marginal costs and marginal benefits per unit of water are equal in all uses.

[6] Social equity is when the costs and benefits associated with changes in the allocation of water are equitably distributed among affected parties. Ecological sustainability is whether water use is sustainable over the long term.

expected to reduce food costs and encourage rural development, which has a high social value.

Consider first the equity arguments that arise from a lack of ability to pay. The ability to pay may be surmised from the capital and O&M costs borne by farmers dependent on groundwater for irrigation purposes. Bazza and Ahmad cite several telling examples: In Pakistan, the selling price, in informal markets, for water from private tube wells is Rs. 120 per hour at one cubic foot per second. This price is twice that of canal water for an equivalent quantity and for the same crops. Yet 30% of water that farmers relied on in 1997-98 came from tube wells. The ratio of current canal water charges to gross income is between 0.57% and 1.22% depending on the crops. The authors estimate that even if the prices were doubled, the ratio of water charges to gross income would be between 1.74% and 3.66% for different crops, which is still much lower than the average of 6% in Asian countries. In Syria, even though O&M costs for well water are more than twice those for water from government irrigation networks, well water is applied to 59% of the irrigated area, again indicating that farmers are willing to pay for necessary O&M costs.

While acknowledging the significance of equity in implementing a pricing policy, Tsur et al. detail a practical approach based on economic principles of marginal and average cost pricing. They conclude that water pricing can be an effective instrument for efficient allocation without affecting income distribution among the irrigators in the same perimeter. Their approach can be used to establish some pricing benchmarks, based on available data. The authors focus on the idea that from society's point of view, when the interests of both farmers and suppliers are maximized, then it can be assumed that water is being efficiently allocated and used. This implies that the price of water should allow the farmer to use the resource productively while, at the same time, the supplier has an incentive to supply it. The farmer will continue to demand water so long as the last unit employed is still beneficial to production. The limiting point is when the benefit from and cost of the marginal unit of water are equal.

The total cost of water supply includes a fixed component and a variable component. Costs of pumping, conveyance, temporary labor, and operations and maintenance constitute variable costs. Depreciation, interest payments on facility, permanent labor and administration, and some operations and maintenance (which have to be undertaken whether water is supplied or not) are fixed costs. From the supplier's perspective, as long as the cost of supplying the last unit of water is covered water can be supplied. The marginal cost of supply, however, does not address the investment sunk in fixed costs. So, in the long run the supplier will prefer to charge a rate equal to the average of supplying a unit of water, that is the total of fixed and variable cost per unit of water. Typically, in irrigation schemes, fixed costs greatly exceed variable costs, signifying that the average cost will be greater than the marginal cost of supply. When purchasing water at the marginal price (equal to marginal cost), farmers make a lot more profit than they would if they covered the average supply cost. In the short run, the joint surplus of farmers and suppliers is maximized when price is based on marginal cost. The allocation of water is economically efficient but fixed costs remain unpaid. Average cost price, on the other hand, while adequate to cover fixed and variable costs of water supply, runs the risk of driving the farmer out of business.

So, the authors suggest two options: (1) Block rate pricing can be employed to transfer wealth between farmers and suppliers, while still maintaining efficient allocation. In other words, if the rates in some of the blocks are high enough that they contribute a part towards fixed costs, then the supplier may be willing to charge just the marginal cost in some other blocks. The farmer can thus continue to irrigate since the price of the last unit may still make it worthwhile. However, block pricing must be charged either to the individual farmer or groups of farmers on a volumetric basis. In the long run, block-rate pricing may affect exit from and entry into irrigation. For these reasons, (2) an alternative approach is to charge an area-based fee separately to address fixed costs and apply the marginal price volumetrically to cover variable costs.[7]

The paper demonstrates the use of programming techniques to derive the "shadow price" of irrigation water, which reflects the marginal value of water for different crops with differing input requirements and input prices. The shadow prices for different levels of water use define a "derived demand function" for water. Plots of the demand curve against

[7] The idea is similar to pricing in the cell phone industry. The marginal cost of making an additional phone call is minimal. But the cell phone companies have invested heavily in extensive networks and purchased bands of frequencies to provide the service. This means that the average cost of each phone call, including the capital costs, is higher than the marginal cost. So as in the case of area-based irrigation water pricing, heavy cell phone subscribers pay a higher flat fee per month than those on the basic plan. A variable component is applied when phone calls exceed certain limits of airtime, which is akin to the block rate pricing for water.

plots of marginal costs are then used to estimate the joint surplus of farmers and suppliers for different case studies.

For example, in the Loskop Irrigation Scheme in South Africa, farmers pay an area-based fee of about R24 per ha and a water tariff, depending on the crop, to cover variable costs. The irrigators' surplus is R 90.5 when water price is R 0.07/m^3 for tobacco, citrus, table grapes, and peas. The joint surplus is R 55.9 million because farmers are transferring R 34.6 million (for 2000/2001) to suppliers, which are the fixed costs for that year. The authors point out that differentiating among crops when applying volumetric pricing, only serves to encourage some crops relative to others, by subsidizing them (Tsur et al.).

The Harran Plains irrigation district in Turkey is an example where there is more scope for efficient allocation of water because the volumetric charge is missing. Thus farmers continue to use water until its value to them is zero, which implies a great deal more water than farmers would employ if they were charged a tariff.

The study further shows that the effect of water prices on income distribution is small. So, water pricing can theoretically be an effective instrument to put water to its best use through efficient allocation without triggering big changes in income distribution, as is feared by those voicing concerns about the social consequences of a water pricing policy.

Water pricing is one of many policy interventions to mitigate water scarcity. It provides the economic and financial justification for the development of additional supplies from both conventional and unconventional sources. It has two key roles: (1) an economic role of signaling the scarcity value and opportunity cost of water to guide allocation decisions both within and across water sub-sectors and (2) a financial role as the main mechanism for cost recovery. While so far we have focused on the economic role of water pricing, the financial role is not less important. Both functions help jointly in achieving the ultimate goals of sustainability, efficiency and equity. To achieve, these goals, however, water pricing or cost recovery must often be reinforced by other government policies, such as energy or trade support policies.

Many policymakers promote the concept of full cost recovery. For example, the European Water Framework Directive (WFD) calls for full cost recovery; development institutions also often condition disbursement of loans on full cost recovery. Although the terms 'full' and 'cost' are frequently used, such terms do not always mean the same thing to everyone. We learn from Massarutto's study of Italy, France, Spain, Greece, and Portugal, that in these countries the O&M cost recovery rate varies between 20 and 100% and machinery and infrastructure cost recovery rate varies between 15 and 100%, but is typically at the lower end of the range. Moving from such an uneven distribution of cost recovery rates toward a target of full cost recovery (even without agreeing on what 'full' is) could be an arduous process.

IV. Would Water Pricing Improve Efficiency and Sustainability?

Pricing irrigation water is expected to enhance water conservation and thereby reduce demand. Several papers report on the potential for achieving the above stated objectives by simulating irrigation water use under various price and other agricultural policy scenarios. Generally, models or methodologies are based on mathematical programming techniques in which profits from agricultural production are maximized (or the risk of planting is minimized) under conditions constrained by availability of land, water, labor, markets, and capital. Water demand functions are also constructed to observe price ranges where farmers are most likely to respond to prices. The models trace a variety of reactions to pricing policy changes under different conditions and are very useful devices for advising policymakers on making strategic policy choices.

What do we learn from the simulation models and other case studies about expectations for conserving water in response to higher tariffs? A two-fold message emerges. First, water-pricing policy can be an effective tool but since price elasticity of demand is often likely to be low, complementary conservation tools are needed. Second, a distinction must be made between efficient water use and total irrigation water demand since the gains from efficiency may be offset by greater water withdrawal where farmers expand the irrigated area to augment income. In other words, a distinction needs to be made between efficiency in specific uses and overall sustainability. Table 1 summarizes a large number of studies that examine these questions.

Farmers may react to increased water prices by introducing water saving technology as a long-term measure. This is generally done with the help of government subsidies as in Syria (Varela-Ortega) and Tunisia (Bazza and Ahmad). Alternatively, as observed in developing countries such as Sudan (Bazza and Ahmad), "water stressing" may be practiced, which involves applying less water to the plant than is needed, during some which involves applying less water to the plant than is needed, during some periods in the growing cycle.

Water savings policies are feasible where increasing prices prompt profit-maximizing farmers either to switch to low water intensive crops or install modern techniques, such as, spray , drip and sprinkler irrigation. But more efficient on-farm water use does not automatically translate to total water savings. Any further water conservation, especially when water saving systems are already in place, can only come from reduced demand for irrigation itself, which is when water prices reach a threshold where continuing to irrigate is economically unviable and the farmer has to exit from that activity (Massarutto (1)). At a high enough level of tariffs, profit-maximizing farmers react by shifting to less water intensive crops or opt out of irrigated crops altogether and switch to rain-fed agriculture. This need not always be the case. In situations where opportunities to increase the productivity of water exist, farmers may actually switch to more market oriented, high-value but also more water intensive crops. In this way, where feasible, sufficiently higher prices may cause an increase in total demand for water. On-farm savings result in lower overall demand only if irrigated area is not expanded.

Table 1. Impact of Water Pricing Policy on Water Saving and Sustainability

Case studies	Efficient water use leading to saving	Water sustainability	Comments
Massarutto (1)/Europe (Simulated)	Pricing may lead to more efficient use of water.	Incentive pricing has modest impact on total demand for water, especially if water saving techniques are already in place.	Price elasticity of water is low (between 0 to 0.3) unless price is raised to a level (between 0.05 to 0.15 euro/m^3) such that the farmer "exits" or stops irrigating.
Gomez-Limon and Riesgo/Duero	Substantial improvement in water use efficiency provided price increase is in elastic segments of demand curves. However, elastic segment varies by farmer group.	When water price is between 0.02 to 0.06 euro/m^3, significant reduction in overall consumption is possible	Depending on farmer groups studied, extent of overall savings ranges from 14 to 52 percent at 0.02 euro/m^3, 23 to 70 percent at 0.04 euro/m^3 and 43 to 74 percent at 0.06 euro/m^3.
Bazzani, Di Pasquale, Gallerani, Viaggi/Italy	Beyond a price of 0.3 euro/m^3, farmers shift from irrigated to non-irrigated crops (i.e., from potato and onion to wheat and soybean).		Recommendation: mix of fixed charge for a season's crop and charges per unit of water use (i.e., total charge would be 20 times present tariffs)
Varela-Ortega, Sagardoy/Syria	Modernization affects savings at farm level if irrigated area not expanded. Water-crop quotas or tariffs needed to ensure savings.	Modernization with limited and selective expansion of irrigated areas necessary for sustainability in medium term	Flat fee of SP 3500/ha for permanent irrigation, SP600/ha for winter irrigation, additional fee of 2000 to 7000 SP/ha for public systems

Case studies	Efficient water use leading to saving	Water sustainability	Comments
Shatanawi and Salman/Jordan Valley	Price rise from \$0.10 to 0.15/m^3 causes shift out water intensive crops, such as wheat, barley and alfalfa. Brackish and recycled water is used instead of surface water.	At the current highest price of \$0.05/m^3, small increases in price do not affect demand. Much higher prices are needed to achieve that.	Actual price per m^3 of surface water, in 2000, was \$0.049, brackish \$0.009, and recycled \$0.013 on average for all seasons.
Varela-Ortega and Flichman/ El Viar irriga-	Effectiveness of volumetric pricing depends on policy framework.	For example, water consumption drops by about 15 percent with the equal aid policy.	* Under equal aid policy, farmer subsidies are decoupled from production levels,, thus income is maintained but water is conserved as farmers become more sensitive to prices. .
Bazza and Ahmad/Near East	Pricing alone not a solution. Set of accompanying measures required for success of pricing policy.	Morocco: where individual meters were installed a 5% price increase resulted in a 10% demand reduction, but demand increased where water allocation and charging were done on a collective basis.	Water use efficiencies at farm level can be as low as 35% to 40% (canal irrigation in Pakistan) to 70% with sprinkler systems (Jordan, Morocco, Tunsia). If recycled drainage is included, 70% in Egypt. Otherwise 45% to 60% on average.

V. Trends in Cost Recovery: lessons from country experience

We have discussed above the principles for pricing irrigation water and the likely response to various pricing strategies. In this section, we consider how widespread the practice of cost recovery is and summarize the lessons to be learnt from the existing mechanisms for recovering costs. As defined by Barakat, irrigation cost recovery is the "process of directly or indirectly capturing and directing to public agencies some portion of revenue resulting from government actions to provide irrigation services, regardless of whether or not these funds are used to pay for any construction or operation or maintenance costs (O&M)." The previous section clarified the reasons why investment costs are best treated separately, by perhaps, an area-based fee, while variable fees may be used for O&M costs.

Schur warns, based on the South African experience that previous conditions regarding access to irrigation water and pricing policy can set powerful limits to the possibility of cost recovery and hence, for example, cost recovery strategies must be sensitive to historical inequities. Within such historical limits, an overview of the cost recovery experiences in a sample of countries leads to the following findings:

- The idea that the cost of irrigation water supply must be recovered through charging for water is gradually being institutionalized through legal and legislative means. Some countries like Cyprus (Tsiourtis, Bazza and Ahmad) and Vietnam (Fontenelle and

Molle) have had a long history of cost recovery. Though others, such as Egypt and Yemen (Barakat, Bazza and Ahmad), do not have a formal water pricing policy, there exists even in those countries an understanding that provision of water implies a significant cost as reflected in expensive groundwater extraction, strategic crop choices, and informal trading.

- Collection rates are generally better within Water User Associations (WUAs) than directly from individual farmers, especially when estimated fees are collected ahead of the irrigation season or the agricultural year (Aguilar).
- Farmers pay for services received, so they prefer to see their taxes used for improvement in water delivery services instead of being dropped into the same pot along with other taxes in treasury departments (Bazza and Ahmad, Fontenelle and Molle).
- Effective cost recovery will need charges to be pegged to inflation rates especially where these rates are high (Cakmak).
- Cost recovery is lower during droughts (Hassan, Mejias et al.).
- In most cases, charging is aimed at recovering some or all of the O&M costs, but capital costs are addressed to a lesser extent (Hassan, Bazza and Ahmad, Yaozhou and Bingcai, Aguilar). Most fees do not cover costs of rehabilitation, which are either subsidized by the State, or borrowed directly from foreign sources. Otherwise, systems are simply left to deteriorate.
- Transparency in accounting and management is necessary both to encourage farmers to pay for services and also to induce them to save water (Fontelle and Molle).
- Liberalization of prices of irrigated crops and subsidies for modern equipment may be needed to make water tariff increases more acceptable to farmers, for example as in Tunisia (Bazza and Ahmad). In Morocco, the prices of strategic crops such as sugar beet and sugarcane need to be liberalized if farmers are to accept higher prices for water in large scale irrigation schemes (Ait Kadi).

Table 2 presents examples demonstrating the above observations from country experiences with charging and cost recovery.

Table 2: Charging for Water and the Cost Recovery Rate

Country	Charging Scheme	Strategy for Cost Recovery	Cost Recovery Rate	Comments and key issues
Morocco	US$0.02 for gravity irrigation; US$ 0.02-0.04 for pumped water; US$ 0.04-0.053 for sprinkler schemes. (depending on the ORMVA)	40% of investment cost from beneficiaries and 60% from budget; energy tax indexed to electricity tariff; 100% of O&M to be covered by water tariffs. Small farmers (<2.5 ha) have different CR scheme.	Recovery of water tariffs was 70%-73% from 1990-1997 and 52% –58% from 1997-2000	Current decrease in recovery rate is believed to be due to droughts. Allocation of water occurs through planning and not pricing. Costs of extension services and rehabilitation are not included in fees.
Syria	US$ 40 to 120/ha for investment costs; flat fee of US$ 70/ha for permanent irrigation and US$ 12/ha for winter crops	Direct fee for part of investment costs amortized over 30 years; flat fee represents average actual O&M costs in the main irrigation networks.	90% of O&M costs	Collection rate is impressive but only applies to government-irrigated networks. At the same time, 59% of irrigated area depends on well water (with costs covered by farmers) and lowering of groundwater levels is a problem.
Pakistan	Per area fee by crop, US$ 0.6 per acre-inch for fodder and US$ 3 for sugarcane; other crops in between	Government subsidies cover cost of rehabilitation of watercourses. Cultivation intensity and farm size determine water charge.	30%-70% of O&M costs	Water charges not related to quantity of actual canal water applied so rate increases have little effect on economic efficiency. Also water revenues are pooled with other taxes and lose relation to O&M.

Country	Charging Scheme	Strategy for Cost Recovery	Cost Recovery Rate	Comments and key issues
Tunisia	US$ 0.066 at the national level; US$ 0.025-0.08 across regions	Policy aims to cover O&M costs in first phase. Preferential tariffs for cereals and for reuse of treated wastewater in agriculture. 16% of wastewater treatment is covered by tariff.	Recovery of O&M costs: 70% in 1991 to 115% in 2002	Water prices are to be increased at 15% per annum in nominal terms. Policy has been resisted by farmers but assisted by liberalization of prices of most irrigated crops and subsidies for modern irrigation equipment.
Cyprus	Volumetric pricing; US$ 0.1078/m^3	The goal is to recover 38% of weighted average unit cost of irrigation water	Charge since 1992 has been 34% of weighted average unit cost of irrigation water	Sum of annual costs of all existing projects divided by all irrigation water from the projects is the weighted average unit cost of irrigation water
China	Average national irrigation water tariff is 0.026 yuan/m^3 in 1997	Water tariff accounts for 36% of supply cost on average; water supply costs and a profit are to be recovered for cash crops but only water supply costs for grain crops		Costs are more in the North than in the South due to greater rainfall in the South. Pricing is highly centralized and only meant to recover costs.
Mexico	Charges set by WUA. Estimated O&M budget divided by the water allocated to the module is the tariff for the year. Average water cost is US$40 per ha per year.	Users pay more than 70% of O&M costs and the government subsidizes around 15%.	In most irrigation districts users pay the WUA before the irrigation cycle; otherwise a flat rate per season per ha is charged; recovery is 90% to 100%	Transfer programs to WUAs have raised user payments from 39% of the irrigation districts in 1990 to almost 80% in late 1990s.

Coun-try	Charging Scheme	Strategy for Cost Recovery	Cost Recovery Rate	Comments and key issues
Turkey	Capital cost was US$ 0.3 to 0.7 per ha in 1998 across regions. Examples of O&M fees from a region: wheat US$ 22, cotton US$ 76 per ha, for gravity irrigation; pump irrigation is more expensive, US$ 56 per ha for wheat.	Annual area-based fee consists of capital cost and O&M costs. Capital cost recovery not to be charged for 10 years after project completion; O&M cost collected for the previous year.	Collection rates were 32% in 1991 and 37% in 1998; highest rate was 50% in 1985. WUAs collect annual fees for O&M and investment before irrigation for the year. In 1998 nearly 76% of the planned budget was collected.	Annual area-based fee for DSI operated schemes; capital cost varies by region; O&M costs vary by region and crop No volumetric system and very low capital cost recovery, no inflation adjustment despite 70% inflation rate.
Vietnam	Fee expressed in kilos of paddy and converted to cash based on official rate for a kilo of paddy. For example, water fees in the BHH polder are 5.8% to 7.7% of annual paddy production; 464 kg and 639 kg per ha per year for single pumping and double pumping respectively.	Area-based water fee calculated for crop and irrigation type. Fees include water diversion and drainage and O&M costs. Fees are paid along with taxes such as land tax and road maintenance tax so farmers do not know what they pay for water.	Water fee recovery from cooperatives has exceeded 92%; but IDMC collection rates for water diversion fees from the IDMSCs were 55% and 72% in 1998 and 1999 respectively.	Polders may be served by partly by cooperatives and partly by IDMSCs. A water diversion fee has to be paid to the cum. Pricing mechanism aims at financial stability and not at water saving. Transparency in management is main issue.

Sources: Bazza and Ahmad: Morocco, Syria, Pakistan, Tunisia; Doukkali and Hasan: Morocco; Tsiourtis: Cyprus; Yaozhou and Bingcai: China; Aguilar: Mexico; Cakmak: Turkey; Fontelle and Molle: Vietnam

Notes:

DSI: State Hydraulic Works in Turkey

IDMSCs: sub-companies of Irrigation and Drainage Management Companies in Vietnam.

Polder: is a hydraulic or irrigation unit in Vietnam. BHH is the Bac Hung Hai polder.

Cum: name given to an irrigation group in Vietnam. IDMSCS pay a water diversion fees to the cum.

An example of how water pricing is implemented in practice is provided in the context of Cyprus in Box 1. Pricing schemes in other countries and regions within countries differ with respect to several elements such as, the costs taken into account in their calculations, the weights given to various costs, assumptions about the economic life of projects, time of collection relative to the irrigation season, and penalties for delayed payment or non-payment.

Box 1: Water Pricing in Cyprus

Cyprus is an example of a country experiencing a high degree of water shortage and has a long history of charging for water. Irrigation water pricing, though more advanced than in many other countries in the region, aims at discouraging wastage rather than achieving economic efficiency. On the other hand, charges are differentiated by dependability and mode of service. The EU's Water Framework Directive is expected to increase irrigation water charges in the Mediterranean states to disproportionately high levels relative to those in other member states, because of the high level of water scarcity they face and the extra infrastructure cost they bear to overcome it.

Water charges include the interest on capital, amortization of capital cost over the life of the project, insurance cost of works, operations and maintenance covering energy and management costs for the project. Charges are based on the weighted average unit cost of water, which is either calculated based on annual costs and quantities or on costs and quantities expressed in present worth terms. The rate of interest generally applied is 8% and the economic life of the projects is assumed to be 40 years from start of operations. The weighted average cost per cubic meter of water is the sum of annual costs from all existing projects divided by total water delivered from these projects. Alternatively, a unit cost of water is calculated for each project by aggregating the unit capital cost for the project and the annual cost of operations and maintenance per unit of water. Here, the annual cost for each project consists of operations and maintenance, energy, materials, equipment, wages, salaries and administration costs of the Water Development Department staff. In general, water charges to the beneficiaries are required to be at least 38% of the weighted average cost of irrigation water per cubic meter and, though they are expected to be less than 40% of such costs, the charge may go up to 65% of the weighted average cost if capital costs are very high. The water meters are read every two months and the consumer is expected to pay within 90 days of the date of the bill. Unpaid amounts bear an interest of 8% per annum and further delays could lead up to a $US1000 in fines or have their water supply cut off. In practice, 34% of the weighted average unit cost of irrigation water is charged because a series of droughts made it politically difficult for the government to raise the charges further.

Source: Tsiourtis

VI. Pragmatic Lessons for Pricing Policy

Since the effects of price on overall water demand and sustainability are ambiguous (see discussion in Section III) and since defining, measuring, calculating, and implementing full cost charging and recovery poses many practical difficulties (Section IV), several authors have emphasized the importance of a mix of policies necessary to render pricing an effective tool (Hellegers, Burke, Bazza and Ahmad, Varela-Ortega and Sagardoy, Bazzani et al.). This view stresses:

- The availability to authorities and to farmers of suitable modern techniques to allow some degree of water control, complementing institutions that permit flexibility in irrigation decisions.

- The importance of gaining farmer acceptance.
- The possibility of using water markets, though recent experience is not yet encouraging.

Since these implementation challenges are not easily met, several authors recommend a price level that lies in between that for a purely private good and a purely public good (see, for example, Abu-Zeid, Facon, Hamdy and Lacirignola, Hellegers, and Massarutto (2)). It is widely believed that a water pricing policy even below full cost will convey the value of water to users (Tsur et al.), reduce pressure on budgets, and promote new technologies compared with the shadow value of water for the user. If the price is high enough, a water pricing policy can still be effective in demand management.

Technological improvements are necessary to enhance effectiveness of a pricing policy

Modern techniques are expected to reduce water withdrawals and increase crop yields through focused application of water. At the same time, institutional and organizational changes are necessary to chart out procedures to realize the benefits of applying the advanced techniques. These include steps to organize water delivery at the level of tertiary canals, to streamline fee and tariff collection, to maintain a constant flow of information among supply agencies and users, to arrange rural credit mechanisms, to provide extension services, to institute legal codes to establish water rights when necessary and to resolve conflicts. The responsibilities of the government and those of other agencies must be clearly defined. Several examples illustrate the role of appropriate use of technology to enhance the effectiveness of pricing. But the limitations are also evident.

Prices and quantities have to be related to each other for water pricing to be effective in saving water. This point is exemplified by a case in Morocco, described by Bazza and Ahmad. In a gravity irrigation scheme run on a collective charging system, water price levels had no effect on water demand. However, significant savings were observed in a sub-section where farmers using sprinkler systems were equipped with individual water meters. An increase in water tariff by 21% induced a reduction of 5% in water demand and 38% increase in crop intensification, which reflected an actual reduction of 32% in water demand. In comparison, in a roughly similar sub-section where the land ownership pattern did not allow the use of individual meters, an identical increase in water tariff resulted in a 6% increase in water demand and a 15 % increase in crop intensification, estimated to reflect an effective decrease of 7.8%. While attractive, metering and measurement are impractical in most existing systems; in particular, the cost of installing new equipment can be very high (Abu-Zeid). Alternative ways to measure water delivered to the field, including proxies, are valuable (Tsur et al.).

Delivery infrastructure and distribution rules that meet farmers' requirements are essential for a pricing policy to work (Facon). There is considerable divergence between stated operation policies and actual policies and rules and subversion of policies observed in Asian irrigation, for instance. Rules that govern the flow of water between the reservoir, main canal, and channels have to define a pattern of delivery that is consistent with the irrigation strategy the farmer considers feasible. Failing this, farmers engage in illegal water trading, pump water from distribution canals and drains, tamper with controls, and use excessive amounts of groundwater to obtain their water supply in whatever way they can.

Modernization rather than mere rehabilitation of the existing systems is another aspect of improvements necessary to meet today's changed goals (Facon). Further, rules that control the operation of the system have to adapt to changing conditions. If, for instance crops have to be diversified to respond to price increases the irrigation system may have to be reconfigured to include new features. Like the warabandi systems in colonial India and Pakistan, many existing systems are old and are based on conditions and objectives that prevailed when they were put in place. This system was designed and applied where there were no reservoirs to regulate supply and water is delivered according to a strict schedule, which is too rigid and hampers the farmer's ability to control the use of water.[8] A modern system is one that has sufficient flexibility built into the design so that operators can manage it and farmers can take advantage of the flexibility in water deliveries by switching to high-value crops or choosing among alternative cropping patterns. This is particularly important if farmers have to change from a subsistence orientation to a commercial orientation. The ability to measure and control the exact timing and quantity of water received is essential for volumetric pricing or if any trading has to occur. Systems also have to overcome problems that arise due to small farm sizes. Finally if farmers must respond to envi-

[8] At a later stage Tarbela, Mangla, and Bakhra reservoirs were impounded and are now part of that system.

ronmental regulations regarding discharge of effluents with chemical pollutants, they will need adequate drainage infrastructure (Facon).

Upgraded managerial skills have to complement improved infrastructure and distribution rules. Tasks to be managed involve extensive record keeping, responding to delivery requests, monitoring water availability and allocation, financial assets, equipment and maintenance programs. Often pricing structure is based on the management and operation of the surface canal system, as stated in the books. However, the actual flow of water within the system may involve conjunctive use, re-circulation of drainage water, and other "losses." The corresponding managerial and monitoring tasks are all also critical to water use efficiency and productivity (Facon).

On-farm water saving technology must meet local conditions. Technologies, like drip and sprinkler systems require a continuous supply of water. Therefore, they are generally found to be more suitable for private wells rather than for public surface irrigation schemes where water supply is by rotation and consequently intermittent. The limitations faced by farms, in Syria, where wheat and cotton are grown present a case in point. A sprinkler system is more suitable for wheat but not for cotton while a drip system is more suitable for cotton than it is for wheat (Varela-Ortega and Sagardoy). The significance of infrastructure being flexible enough to respond to prices is especially evident in systems meant for rice paddy monoculture where switching to dry season crops presents serious challenges (Molle).

Facon proposes the use of service agreements between irrigation service providers and farmer associations to ensure consistency between design standards, operation strategies, service levels, and water pricing. Objectives and operational strategies must be consistent with what is feasible given the infrastructure. A service agreement, including costs, must be made on that basis. The level of service to be achieved must be agreed upon and the flow control systems and human resources required must be ensured before the project begins.

Climatic factors affect responsiveness to water pricing. In a study on irrigation in Southern Spain, Varela-Ortega and Flichman present evidence to show that water availability is a factor and that pricing is not effective in a drought situation. Salman et al. also substantiate this finding in the Jordan Valley. Water demand is elastic for long intervals in the safe yield and wet year scenarios. However, when water supply is cut by 15% water demand is inelastic.

Gaining Farmer Acceptance

Also, for pricing policies to be effective, the idea of charging for the extraction and delivery of water has to be made acceptable to farmers. In many countries around the globe, farmers are used to very low prices or even free water supply (Bazzani et al. discuss the situation in some Mediterranean countries and parts of Italy, while Hamdy and Bazza and Ahmad discuss it in Near East countries). Hellegers correctly notes that this reflects, in part, the limited ability to pay in the agricultural sectors of several developing countries. Farmers are likely to resist a pricing policy for water supply because of the negative impact on their incomes, especially when there are few opportunities to recoup the shortfall elsewhere and particularly if there are no visible signs of improved water supply. Perceptions of income decline as a result of price increases are corroborated by many studies. Some of these studies (e.g., Bazzani et al., Varela-Ortega and Flichman, Gomez-Limon and Riesgo) also project significant negative impacts on employment in irrigation and the agricultural sector.

Water users must feel that they are receiving a reliable service for the prices paid and that the price is no more than the cost of services rendered. This is the only way in which water pricing will be acceptable to users because they do not know whether there is economic justification, efficiency or equity but they will understand that they are paying for what they are receiving and believe that it is supplied to them at least cost. The agency providing the service would have to be financially autonomous. This would allow a system to exist, where it is in the interests of the providers to maximize their income, by charging a higher fee for more reliable service (Abu-Zeid).

In Thailand, the Royal Irrigation Act of 1942 stipulated that charges could be collected from water users, but the revenue could not be transferred to the State. They were to be set aside specifically to be ploughed back into irrigation development (Molle). Barakat cites the “crucial importance of linking cost recovery to accountability for the services provided”. In his paper on irrigation in Egypt’s Nile River Basin, Barakat recommends linking water fees to service charges in order to impress upon users that water provision incurs costs. In the context of the Nile River Basin, the link may be more transparent if water is supplied from the Aswan to smaller units (called Directorates) so that charges could be set according to costs incurred at the local level.

Other studies emphasize the need to address equity issues to enable farmers to conform to water pricing reform. Bazza and Ahmad cite poor areas of agriculture-based economies, like regions in Tunisia, Yemen, Algeria, Egypt and Morocco as examples where in spite of serious water shortages, water productivity is low. They suggest that poverty itself restricts farmers' capacities to invest in water saving mechanisms and enhancing the quality of output.

In addition, the history of access to water must be taken into account in trying to gain farmer acceptance for irrigation water pricing. For example, as noted above, Schur describes how the new pricing strategy in South Africa was conditioned by the need to redress the inequality in access under the apartheid regime. Taking into account this history, the new pricing strategy is to allow 25 liters per capita per day free of charge to the water services authorities, a policy that will benefit 18 million people who have been without access to basic potable water. Further, previously disadvantaged farmers are to be allowed, for a limited time, access to irrigation water from Government schemes on a concessionary basis.

Some experts suggest that Water User Associations (WUAs) may be used as an interface to collect revenues (Hamdy). Such collective organizations maintain small canals and allocate the water among individual users. By being able to represent farmers' needs and interests to the irrigation authority, they can also aid in collecting revenues from farmers. In some contexts, as in Bangladesh, promoting stakeholder participation is seen as essential to irrigation water policy reform (Quassem). In a Tunisian case study, Lebdi et al. assess the effectiveness of WUAs by examining the management and performance of hydraulic networks in irrigation. The outcome is regarded as very successful in terms of measuring volume of water delivered and settlement of conflicts.

However, it has not always been easy to establish WUAs and realize the benefits that they are designed to provide. Tomosho et al. view water user groups as a practical means to overcome the difficulty of providing water-measuring devices to several small farms, especially where farm sizes are often small as in Japan. They note, however, that farmer groups can hope to benefit economically from saving water, provided individual farmers cooperate by resisting a tendency to use more water than other members in the group. In Turkey, while initial results of programs to transfer management functions to irrigation associations were promising, several problems with respect to the transition process have subsequently surfaced. For example, initial gains included a doubling of irrigation fee collection rates and savings in government expenditure due to reduced staff levels (Yazar). However, since members of the associations are mayors and other administrative officials elected for purposes other than to represent the interests of water users, they function like government agencies rather than institutions based on participatory management. Transfer Agreements are not clear about titles to assets and time frames for cost recovery, thus diminishing the associations' incentives to make long-term investments (Unver and Gupta). Yazar points out the lack of a charging mechanism for bulk water to irrigation associations as a disadvantage to demand management.

Can Water Markets Help?

Markets for water can in principle be used to reallocate water to its most efficient usage (see, for example, Louw and van Schalkwyk, Tisdell and Ward, McCann and Easter). Water markets could substitute for the current system of administrative pricing and allocation of water. Unlike in the case of administrative allocation, the role of politicians and bureaucrats would, in principle, be minimized if water markets were to operate effectively. However, for the most part, water markets are in their testing stage. A number of institutional changes are needed before they can play a more prominent role.

Several factors explain why water markets have not yet become more widespread. Easter and Smith note that the infrastructure to move water between buyers and sellers across irrigation districts is typically lacking and hence most of the trading occurs within local areas. At the same time, the incentives are weak to create such an infrastructure since a view prevails that water is a necessary resource for local development and therefore not to be traded outside—in particular, trading outside the local area may hurt the environment and downstream users of water.

There are various negative externalities to local areas from selling water to other districts. Decrease in irrigation and agricultural production through land fallowing may have an adverse impact on local business income. If groundwater recharge does not keep pace with extraction for sale then lowering of the water table is an externality that will increase pumping costs for all farmers. If downstream users in the local area do not receive adequate water from return flows upstream because water is being sold instead of being used for local agriculture, then they are likely to oppose the trade. Finally, there could be damage to in- stream water services such as wildlife and fish habitat. Some of the externalities may arise even from local trading. Non-traders using the same canal as sellers could either bear an extra cost of maintenance or even receive less water due to overall reduced water deliveries. Non-irrigation water users, especially those receiving water before it flows to the fields, are particularly affected from the low pressure (for example: in the Kirindi Oya irrigation system in Sri Lanka; see Easter and Smith).

As with the case of cost recovery, history plays a role in determining the political support for water markets. In a comparison of irrigators in the states of New South Wales and Victoria in Australia, Bjornlund finds that those who lose annual water allocations in the transition to water markets, not surprisingly, oppose the creation of such markets. He notes that such opposition is least pronounced in Victoria because the loss of annual water allocation is less severe in that state due to a history of more conservative allocation policies.

Institutions need to be developed to address the concerns of the stakeholders, if water trading is to be expanded. Sellers need mechanisms to resolve conflicts over water rights and changes in water use, while third parties (not involved in the trade) need protection against damages that may be inadvertently inflicted on them. Easter and Smith suggest that WUAs could handle informal arrangements when sales are local.

To limit the effects of these potential externalities, certain restrictions on sales have been contemplated. A water right holder may use the water for irrigation but only some part of it is actually consumed for his production needs while the rest constitutes return flows, which has value to others. Restricting sales to only the water that is consumed would, in principle, maintain the volume of water available for return flows for others in the district. Others would restrict the sale to 50% of the water right but this is unfair to farmers using water saving technology. Permits can be effective in the case of new wells and establishing pumping districts to limit pumping rates and to deal with some externalities from groundwater sales. But these will need enforcement since volumetric water rights are the basis for pumping districts.

According to Nieuwoudt, water markets in South Africa have, in the past, tended to move water to the most effective use. Discriminant analysis based on a cross sectional survey of 54 irrigation farmers, in 1997/1998, showed that water trading in the Lower Orange and Fish/Sunday rivers moved water to where the returns per unit used were highest, which in this case was table grape irrigation. However, following the new South African Water Act of 1998, farmers were led to feel less secure about their rights. In water scarce areas, farmers with unused water rights (sleeper rights) can lose their rights as a result of the new law. Also, ministerial consent is required to enable a water transfer. As a consequence, trading of water has declined.

And finally, the role of transactions costs in selecting optimal pricing or a cost recovery scheme was not highlighted enough in the papers presented at the conference. It is often the case that a comparison among various pricing schemes fails to account for the collection cost, measurement of consumed water, thefts, and alike. Such transactions costs could be significant and affect the choice of the preferred scheme.

VII. Conclusions

Governments view pricing as an important policy tool for achieving financial sustainability of water supply agencies. As such the policy objective of many governments is to collect as much of the proceeds as possible from users, subject to political and social constraints. Although this is an important policy objective, it ignores the consideration of efficient water allocation consideration and heightens political tension by not being able to collect sufficient revenue by raising the fees high enough, and then by removing most or all proceeds from the sector.

The paper argues that it is not just that pricing water can be an effective tool in demand management but how it is implemented and regulated, with supporting institutions that determines its effectiveness. The examples for both pricing and cost recovery suggest that a combination of the two, where applicable, could achieve both financial sustainability and economic efficiency. There is a distinction, however, between levels of cost recovery. Lately, western countries are promoting the notion of full cost recovery. While it is true that countries define full cost pricing according to their own requirements and conditions; a distinction is still made between cost of O&M and cost that includes fixed cost and externality components. In any event, the practice of full O&M cost recovery is gaining acceptance, as we observe from the several examples that are included in the paper.

As reported in the country papers, a great deal of the level of success and sustainability of water pricing/charging reforms in irrigated agriculture has to do with several prerequisites:

- Institutional reform must ensure reliable service to make adequate water pricing acceptable to farmers.
- Transparency in management and involvement of farmers in decision-making.
- Empowerment of users has several advantages. WUAs could be useful in mitigating government transactions costs and fostering sense of ownership among irrigators.
- Water pricing/charging reforms of irrigation water also have to be supported by other appropriate reforms (e.g., other inputs, crop support prices) in the agricultural sector to realize maximum gains from changes in irrigation water pricing.

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Annex 1: Various Definitions of Water Use Efficiency[9]

In simple terms, water use efficiency (WUE) in an irrigation system refers to the ratio of water volume actually applied at the crop root zone to the total water volume entered into the main delivery system. Traditionally, the efficiency of water use has been looked upon from a technical point of view. The technical efficiency used in engineering design, and economic efficiency used in measuring the overall rate of economic returns from the irrigation system, however, provide only a partial basis of measuring efficiency and implementing means to improve both. The term "efficiency" in irrigation water use thus should not be limited to the technical efficiency or to the water conveyance and distribution.

Technical/Engineering Efficiency
The technical concept of efficiency of irrigation water use is usually measured by the ratio between total water supplied by the system to total water taken by the plant. Technical efficiency differs from the overall concept of WUE in that it is measured in terms of physical layout of the canal systems such as conveyance, distribution and application efficiencies. Technical efficiency, therefore, accounts for the loss of irrigation water due to seepage and percolation, and evaporation during conveyance and water use at the farm level. For example, the irrigation efficiency of the major surface irrigation systems of the world with flood systems is estimated to be very low, between 37-50 percent.

Economic Efficiency
The economic efficiency of irrigation water use is measured in terms of crop output per unit of water applied or overall financial returns in terms of net benefits from the project/perimeter/farm/field. Economic efficiency, usually measured in terms of cost-benefit ratio, has long been used in investment decision making, which seeks to derive maximum return from the irrigation system over its life period. The definition of WUE itself is rooted in the concept of economic efficiency which implies that water needs to be used with maximum possible efficiency and could be defined in various ways:

- In general, economic efficiency indicates the Pareto optimality condition and considers not only the private costs and benefits but also the internalization of the non-financial social costs and benefits.
- Economic efficiency also refers to the maximization of overall socio-economic net benefits from different water using sectors, and seeks to minimize inter-sectoral and intra-sectoral socio-economic opportunity cost, including re-allocation of water among sectors and users.

ET productivity/Productive Efficiency/Basin Efficiency
Among many definitions of WUE, the use of water productivity via crop per unit of evapotranspiration (ET[10]) is most appropriate. Since agriculture has the highest consump-

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[9] Based on World Bank, 2003.

[10] ET can be divided into three components: (a) consumptive use related to human activities; (b) beneficial ET; and (c) non-beneficial ET. Consumptive use is the water transpired by agricultural plants (including pasture) in irrigated and rainfed areas, and water consumptively used in other human activities; Beneficial ET is the ET from forests, non-agricultural but environmentally significant green-areas, wetlands, lakes and their banks, and rivers and their banks; and non beneficial ET is the ET from reser-

tive use rate, the objective of water use efficiency in agricultural and irrigated agricultural sectors should be to maximize the production and the value of production per unit of ET. Other factors such as the need to generate employment and to reduce poverty also should be factored into the analysis. Maximizing the production and value of production per unit of ET needs to be looked at from several angles.

From the agronomic perspective, it can be obtained by improved crop genetics, improved soil fertility, reduced soil salinity and sodisity, improved cultivation practices, cropping pattern adjustments, soil moisture management, maximum beneficial use of precipitation, etc. These factors would be equally important in rainfed and irrigated areas. In irrigated areas it should consider improved drainage, requirements for leaching salinity and sodisity, soil moisture management, minimizing non beneficial ET due to leaking systems and poor on-farm practices, and targeted irrigation systems such as drip systems (Olson, 2003).

Since (e.g., Perry) externalities in terms of return flows need to be considered and, as such, a pricing strategy needs to keep in mind the overall need of the water basin and not just of individual farmers or production and consumption sectors. Efficiency calculated at the basin level may be higher than those calculated at a field level.

The term "economic efficiency" thus needs to be considered in a broader perspective and should include factors involving technical efficiency, opportunity cost of water, and externality costs generated by the irrigated agriculture.

Ecological or Environmental Efficiency of Water Use

The term ecological efficiency in case of irrigated agriculture is deeply rooted in the concept of environmental sustainability. It implies that available water resources must be managed in a way so as not to reduce opportunity for potential use by the future generations for various ecological reasons. In operational terms, ecological or environmental efficiency indicates that available water should be allocated in such a way that helps to meet the need for consumptive use of water without having adverse effects on the ecological health in the surroundings.

Other Facets of WUE

There are some other concepts of WUE. These are end-use efficiency and productive efficiency often related to on-farm water use, operational measures of efficiency such as institutional efficiency, and finally, temporal measures of efficiency such as static and dynamic efficiency. These various faces of WUE are defined and used in different context under different agro-ecological settings. The reported irrigation efficiency or water loss figures in the developing countries indicate that many irrigation systems are performing poorly with respect to conveyance and distribution. Therefore, raising WUE through reduction in water losses could substantially increase water conservation.

Improvements in the WUE involve measures that directly help reduce different types of water loss and improve the handling of water at various levels and guide decisions regarding the best use of the resource. Various levels of decision-makers can be approached. Farmers' behavior can be affected in order to maximize the returns from or to

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voirs, water surfaces in delivery systems, seepage areas along water delivery systems, ponded areas on poorly leveled irrigated lands, water-logged and salinized lands, capillary flux from high water table areas often due to poor irrigation and drainage practices.

minimize the waste of scarce irrigation water. On the other end, water suppliers have their own list of possible actions to WUE improvements, which imply better management of reservoirs, and coordination efforts in water supply scheduling.