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A study on water's green economy for development in agriculture

Attia El Gayar

Soil, Water and Environmental Research Institute (SWERI), Agriculture Research Centre (ARC), Giza, Egypt

***Corresponding email:** *attiaelgayar@yahoo.com*

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Article Author

Attia El Gayar

Corresponding Author Email

attiaelgayar@yahoo.com

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ABSTRACT

The concept of a green economy has gained currency in recent years as a paradigm for promoting economic growth and increased well-being while protecting the environment and contributing to poverty alleviation. There is no common definition of green economy, but the term clearly emphasizes the economic dimension of sustainability. Not only do the environmental (stewardship) and economic (growth) dimensions coexist in the green economy, but they are also complementary and mutually reinforcing strategies to achieve development. Water scarcity, pollution, and other water related environmental and ecological problems have been increasing rapidly in many areas of the world. Water demand management or making better use of the water we have as opposed to augmenting supply is increasingly proposed as a way of mitigating water scarcity problems. Although the achievements of irrigation in ensuring food security and improving rural welfare have been impressive, past experience also indicates problems and failures of irrigated agriculture. In addition to large water use and low efficiency, environmental concerns are usually considered the most significant problem of the irrigation sector. Environmental problems include excessive water depletion, water quality reduction, water logging and salinization. In some basins (water resources), excessive diversion of river water for irrigation (and other uses) has brought environmental and ecological disasters to downstream areas, and groundwater pumping at unsustainable rates has contributed to the lowering of groundwater tables and to salt water intrusion in some coastal areas. Many water quality problems have also been created or aggravated by changes in stream flows associated with agriculture's consumptive uses. Moving water away from agriculture to uses with higher economic value is one of the main measures widely seen as desirable. This apparent misallocation is often attributed to the failure of government to allocate water rationally. This paper focuses on achieving a sustainable balance between irrigation management and sustainable development and water investments.

KEYWORDS

Sustainable, Development, Environment, Water Investment, Water Resources

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Irrigation has been much appreciated for its significant contribution to global agricultural production and food security over the past 50 years. Currently, more than 40 percent of global agricultural products are produced on irrigated land, which constitutes close to 20 percent of the total global arable land. However, irrigation has also been criticized for inefficient water use, poor system performance and some negative externalities, including irrigation induced soil salinization, groundwater depletion, water-borne diseases and water pollution. To meet the requirements of the world population, which is projected to be more than 9 billion by 2050, food production needs to be increased by 70 percent globally and by 100 percent in developing countries, and irrigation is expected to be a major contributor. Further development and improvement of global irrigation will involve multiple challenges and emerging needs, including:

(i) Increasing water scarcity and competition, which calls for more efficient and productive water use.

(ii) Rapid agriculture restructuring and transformation, which requires more reliable, flexible and diversified agriculture water services.
(iii) Adoption of agribusiness and value chain approaches, which implies a shift from single-headed irrigation to integrated agricultural water management (AWM)
(iv) The shift from the first generation "green revolution" to sustainable agriculture intensification, which highlights social and environmental sustainability
(v) Increasing pressure to meet growing demand for meat and dairy products linked to a combination of population growth, rising incomes and urbanization.

In addition to all these, climate change has brought and will bring more impacts, requiring adoption of a climate smart approach. Irrigation, as the biggest water user accounting for 70 percent of global fresh water withdrawal cannot repeat old modes of development. Innovations are needed to promote productive, equitable and sustainable water management while improving water services to agriculture and rural development. Numerous approaches and tools have been developed and practiced by various partners in recent years to improve irrigation practices, which could be further disseminated in future irrigation investments (Asian Development Bank, 1986).

Human use of water is reportedly increasing with population growth and economic activity. As irrigation diversions rise, they tend to displace water's natural functions and impact on ecosystem health. The cities and economies expand, domestic, industrial and in stream uses also start to impinge on the quantity, quality and timing of water flows, not only for the environment but also for existing and potential agricultural uses. Conflicts amongst and between environmental and human uses intensify, and mechanisms emerge some planned, many unplanned to rebalance sectorial allocations. In many river basins, water resource development has by now reached or exceeded its limits; marginal additional sources provide only very costly alternatives and new projects reallocate water already appropriated for human or crucial environmental use. Handling these conflicts and the sectorial rebalancing that is implied are a major concern of recent literature on water management.

Many believe that better use can be made of the resources at our disposal, that water is too often devoted to economically inefficient, low return (usually agricultural) uses and that reallocation to more efficient, high return (usually urban) uses would increase total economic welfare. Others consider that human uses have been satisfied at unacceptable costs to the environment and that this must be redressed. Associated with issues of value are questions related to the mechanisms of effecting transfers to optimize value (however value is determined). What mix of political, administrative and market mechanisms is to be preferred and under what conditions? And how far and in what ways should the resultant mix be regulated to ensure that transfers are achieved in an efficient and effective manner?

Optimization of sectorial allocations is seen by many observers as one pillar of water demand management, defined as a "policy that stresses making better use of existing supplies, rather than developing new ones". Demand management employs a variety of measures including price incentives, market mechanisms, quotas, subsidies, conservation, treatment, re-cycling, awareness-raising and education such efforts together with decentralization and user participation define a "soft path" approach. Pricing and markets to balance supply and demand have received particular attention.

Making better economic use of water implies emphasis on its productivity and the economic welfare that can be derived from alternate uses. Misallocation is held to be a manifestation of poor water management and to result in economic inefficiency. "The potential for economic benefits from allocation oriented institutional change are not only substantial but also increasing with each increase in water scarcity. The World Bank's policy paper remarks that the value of water differs greatly between agriculture and other sectors "often indicating gross misallocations if judged by economic criteria" but goes one step further in pointing towards a possible remedy: "Setting prices at the right level is not enough; prices need to be paid if they are to enhance the efficient allocation of resources." Price and market mechanisms are thus not only presented as a means of cost recovery and demand regulation but also as a way of reallocating water towards higher value uses (Albiac *et al*., 2006).

The apparent strength of these arguments is predicated on four interconnected assertions:

- That agriculture gets the "lion's share" of all diverted water resources (70% at world level: much more (80-95%) in developing countries).
- That agricultural use incurs large wastage, typified by ubiquitous statements to the effect that two-thirds of water delivered to agriculture fails to reach the crop or that irrigation efficiency is typically 30-40%.
- That the value of water in non-agricultural sectors is much higher than in agriculture, typically by an order of magnitude.
- Those cities are frequently water short, as shown by cities that ration supplies or fail to guarantee water pressure, either permanently or during dry spells, and by urban areas with precarious or non-existent water supply facilities.

The narrative based on these four statements suggests that water is misallocated, with two implicit corollaries. First, responsibility for this is attributed to the State, since it is generally assumed that the State allocates water through centralized management. This assumed failure prompts proposals for pricing and market mechanisms as an alternative. Second, the contrasting share of water used in agriculture with that in other uses suggests that a relatively limited level of water saving in agriculture would easily make up for the additional needs of the urban sector. This is well exemplified that: "The largest single consumer of water is agriculture and this use is largely inefficient as much as half of all water diverted for agriculture never yields any food. Thus, even modest improvements in agricultural efficiency could free up huge quantities of water."

In other words, irrigation profligacy and bureaucratic ineffectiveness help explain urban shortage. Consequently, solutions lie, in part, in demand management in the urban sector but more fundamentally in the improvement of efficiency in agricultural use. Substantial quantities of water can be freed and used in higher value uses, reducing the allocation stress for the common good. Water markets may be instrumental in such reallocation and avoid government failure. This narrative presents us with a riddle: if large economic benefits are waiting to be realized by shifting water out of agriculture through marginal improvements in irrigation efficiency why reallocation and related improvements do seem so problematic?

Why have governments failed to recognize these benefits, especially in contexts where urban bias is pervasive? While not necessarily discarding all the foregoing arguments, we review here the validity of the implicit causal links inherent in the conventional knowledge outlined above. We first briefly look at the validity of the four abovementioned statements, then question the nature of urban water scarcity, and finally analyze empirical evidence on inter sectorial transfers. This will take us to the final section where we attempt to revisit the "allocation gap" and its conventional explicative framework.

Agricultural Water Use and Productivity

Most Water is Used by Irrigation

To stress that agriculture gets the lion's share implicitly establishes a causal relationship between its large share and the allegedly unfulfilled needs of non-agriculture sectors. But irrigated agriculture is a biophysical process that inherently needs a lot of water. In most cases, if practiced, irrigation requires much more water than other consumptive uses. Moreover, agriculture's share is typically dominant when the needs of other activities apart from those of the environment have yet to demand comparable amounts. This has been aggravated by the fact that states have invested massively in subsidized irrigation development for a host of (sometimes controversial) socioeconomic and political reasons, reasons which tend to be forgotten with time.

Where other human uses do in fact compete for significant amounts, the balance shifts and irrigation almost always becomes the residual human use after other needs have been met. To stay with animal metaphors, the lion's share is perhaps better described as the hyena's share. In many cases, however, agriculture compensates for this loss by reusing wastewater (as in Israel and Jordan) and/or by displacing nature. Nature thus can be considered the ultimate residual "user"; this is discussed later (Avis *et al*., 2000). Furthermore, irrigation often utilizes flood flows and other marginal sources that cannot provide the level of dependability required by domestic and industrial users. Irrigation thus typically uses a lot of water at times when it has no alternative use.

In other cases, irrigation and urban networks are disconnected hydraulically and either transfer is impracticable or the costs of storage and/or integration are prohibitively expensive.

Farmers Waste Water

Irrigation's dominant share appears consistent with the conventional belief that farmers waste water: therefore, are not large consumer's squanderers? The alleged wastage in irrigation has been the subject of a large body of literature, and decision makers and the media worldwide continue to refer to classical irrigation inefficiency in order to stress alleged mismanagement or to justify interventions of one sort or another. Without entering into the details of this question, it is important to emphasize that waste is often relative: if water has no other economic use and is not scarce then 'wastage' is of little concern other than for any impacts it has on the environment. During the rainy season or in surplus river basins, low irrigation efficiency is thus typically irrelevant.

Even in water short basins, a loss at one point typically flows back to the river or an aquifer and subject to water quality can often be recycled downstream. If so, efficiency at basin level is much higher than within any individual use level (Bhatia *et al.,* 1995).

In situations of scarcity, tales of irrigation waste are both misleading and unfair to farmers. First, farmers seldom have a say in the amount of water allocated (or not) to them. The second, irrigation managers and farmers respond to physical scarcity by optimizing water's value to them adjusting crops, practices and calendars, and developing conjunctive use by digging ponds or wells and installing pumps. Except in fully controlled on-demand systems the rare exception rather than the rule the stochastic and varying nature of water supply means that the "hidden hand of scarcity" provides both real time and longer term incentives for efficient water use; and prompts (costly) adjustments that are often overlooked.

Low Water Productivity in Agriculture

That urban water uses usually have higher value to society than irrigation uses is predicated on the assumption that their water productivity, *i.e.*, the ratio of total monetary output to the amount of water used, is higher. But this can be presented in ambiguous terms, either because water does not really constitute a production factor or because like is not being compared with like. For instance, "supporting 100,000 high-tech California jobs requires some 250 million gallons of water a year; the same amount of water used in the agriculture sector sustains fewer than 10 jobs a stunning difference". He sees a shift from the latter to the former as providing "tremendous gains in efficiency" as if they were really in competition. There is no indication that high-tech industry is ever short of water and it is equivocal to suggest it competes with agriculture. Only in a few cases is water a significant industrial cost and it is thus often misleading to express total added value in terms of returns to a single factor.

Sustainable Irrigation Water Management

Water scarcity, pollution, and other water related environmental and ecological problems have been increasing rapidly in many areas of the world. "The real crisis in water is a 'creeping crisis' it comes on slowly but it demands a response right now." Sustainable development that is, development that meets the needs of the present without compromising the ability of future generations to meet their own needs is a concept that has gained popularity. Increasingly, researchers and policymakers are advocating sustainable development as the best approach to today's and future water problems.

For water resources management, sustainability implies a notion of equilibrium that simultaneously satisfies water demands and the preservation of the water resources system. This paper focuses on achieving a sustainable balance between irrigation management the largest water use worldwide and environmental preservation. Over the last 30 years irrigated areas have increased rapidly, helping to boost agricultural output and feed a growing population. Irrigation uses the largest fraction of water in almost all countries.

Globally, 70 percent of freshwater diverted for human purposes goes to agriculture, and irrigation water demand is still increasing because the area being irrigated continues to expand. In some countries, the expansion of surface water use appears to be approaching the physical limit and groundwater abstractions are increasingly exceeding rates of replenishment. Meanwhile, industrial and domestic water demand has been increasing rapidly as a result of increasing economic development and urbanization. In some countries and regions, water is already being transferred out of irrigation and into urban-industrial uses, putting additional stress on the performance of the irrigation sector (Chakravorty, 2004).

Although the achievements of irrigation in ensuring food security and improving rural welfare have been impressive, past experience also indicates problems and failures of irrigated agriculture. In addition to large water use and low efficiency, environmental concerns are usually considered the most significant problem of the irrigation sector. Environmental problems include excessive water depletion, water quality reduction, water logging, and salinization. The marked reduction in annual discharge of some of the world's major rivers evident in long-term hydrological records has been attributed, in part, to the large water depletion caused by irrigated agriculture.

In some basins, excessive diversion of river water for irrigation (and other uses) has brought environment and ecological disasters to downstream areas, and groundwater pumping at unsustainable rates has contributed to the lowering of groundwater tables and to saltwater intrusion in some coastal areas. Many water quality problems have also been created or aggravated by changes in stream flows associated with agriculture's consumptive uses. Moreover, inappropriate irrigation practices, accompanied by inadequate drainage, have often damaged soils through over-saturation and salt build-up. The United Nations Food and Agriculture Organization estimate that 60 to 80 million hectares are affected to varying degrees by water logging and salinity. Finally, these irrigation induced environmental problems threaten not only agricultural production systems but also human health and the environment.

Various agencies and researchers have identified broad guidelines for sustainable water resources management. The World Bank proposes a comprehensive approach, emphasizing economic behavior, the overcoming of market and policy failures, more efficient use of water, greater protection of the environment, and moving to "demand management" from the previously dominant "supply management." In 1992, the United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro arrived at the conclusion that water should be considered an integral part of the ecosystem, "a natural resource and social and economic good". More recently, the American Society of Civil Engineers (ASCE), associated with the United Nations International Hydrologic Program (UN/IHP) published a monograph on sustainable water resources management. According to that report, "sustainable water resource systems are those designed and managed to fully contribute to the objectives of society, now and in the future, while maintaining their ecological, environmental and hydrological integrity."

Previous studies have set out several guidelines for sustainable water resources management. They can be briefly outlined as follows:

- Successfully accomplish multiple social, economic, and environmental objectives in terms of adequate water quantity and quality
- Maintain stability and flexibility in water supply so as to deal with extreme events such as flooding, drought, excessive waste discharge, and other anticipated stochastic events
- Minimize negative environmental impacts, especially the long-term cumulative negative
- Realize equity to make equitable water rights possible among spatially distributed water demand sites and between current and future generations
- Achieve financial and economic efficiency
- Adapt to new technology.

No doubt these guidelines could provide some assistance and guidance to those who are actually involved in planning and decision making in specific regions. However, these broad guidelines still need to be translated into operational concepts that can be applied to the planning and management of water resources systems in specific basins. This paper discusses the operational concepts and analytical framework for sustainability analysis in irrigation. These are applied to a case study area, the Aral Sea region in Central Asia, which may have experienced the most serious environmental disaster caused by excessive irrigation.

Concepts of Sustainability

An integrated system comprises irrigation, crop production, and the environment. Irrigation sustains crop production systems.

However, a sole focus on irrigation development, without taking environmental preservation into consideration, is doomed in many regions of the world. Increased soil and water salinity resulting from extensive irrigation practices have already diminished opportunities to develop the crop production system. Although human society achieved a relatively stable balance between irrigation development and environmental preservation for several thousand years; during the last 30 to 50 years that relationship has been destroyed in some regions by inappropriate irrigation practices (Chaudhry *et al*., 1993).

The purpose of sustainable water resources management is to sustain both the water supply capability and the environment, now and in the future. Water supply capability encompasses both the availability of water and the infrastructure to sustain water supply and use. The environment takes into account the water source and the land and air systems that support human production activities. As water demands in agricultural, municipal, and industrial uses change over time because of policy and technological changes, among others the relationship between water use and the environment needs to be continually reviewed and adapted. In river basins where irrigation is the major water use, sustainable water management should ensure a long-term, stable, and flexible water supply to meet crop demands, as well as growing municipal and industrial demands, while at the same time mitigating or preventing negative environmental consequences from irrigation.

Sustainability reflects a systems concept for irrigation water management that is, applying a set of elements that interact in interdependent fashion. Moreover, sustainability, by its nature, implies a dynamic system whose status is determined by a balance of opposing forces or trends. When an accelerating flow of negative forces reaches a threshold beyond which it is impossible or inordinately costly to reverse the direction of the change and return to a more favorable equilibrium, the system becomes unsustainable. Another feature of the dynamic system, perhaps the most pervasive one for sustainability issues, is its association with intergroup and inters temporal externalities.

Measuring of Sustainability

A set of manageable indicators of sustainability based on broad guidelines and principles are necessary to detect problems as they arise and to provide an early warning system for decision makers. The indicators should be monitored and measured on the basis of the performance of natural systems and anthropogenic interactions, and action should be taken once specified thresholds are passed. In particular, the indicators should be helpful in tracing long-term cumulative environmental changes due to irrigation practices, which can potentially create irreversible problems (Cornish *et al*., 2004).

In the context of arid or semi-arid basins where irrigation is the dominant water use, sustainability in irrigation water management can be indicated by:

- Water supply system reliability, reversibility, and vulnerability
- Environmental system integrity
- Equity in water sharing
- Economic acceptability

These indicators, defined at the basin scale, are supposed to be used by basin authorities or related national administrative agencies, instead of individual farmers. Moreover, definitions of these indicators should be analytically sound and measurable in a modeling framework, which will be illustrated in the following:

Reliability, Reversibility and Vulnerability of the Water Supply System

Water supply systems are subject to substantial risk because of inherent stochastic variability and a fundamental lack of knowledge. Sustainable water resources management requires a stable water supply system with enough flexibility to deal with various extreme conditions. Risk has been identified as one of the key sustainability issues in water resources management. The traditional measures of system performance (mean value or variance of some variables) are insufficient to capture risk behavior and additional criteria must be used to quantify recurrence, duration, severity, and other consequences of unsatisfactory system performance. These criteria include reliability, reversibility, and vulnerability.

Reliability represents the probability of a system's success state and is complementary to risk, which represents the frequency of system failure. Reliability, as used in water resources management, comprises three terms: occurrence reliability (the ratio of the number of periods of system success to the number of periods of operation) temporal reliability (the ratio of the time the system is in a success state to the total time of operation), and volumetric reliability (the ratio of the volume of water supplied to the total volume demanded). Reversibility or resilience is the probability the system can recover from failure to some acceptable state within a specified time interval. There are several alternative indices of resilience, including how long the system remains in the satisfactory state and the steady state probability of the system being in the satisfactory state.

Vulnerability represents the severity or magnitude of a system failure. They developed a metric for overall system vulnerability as the expected maximum severity of a sojourn into the set of unsatisfactory states. They emphasized the maximum severity (how bad things are) for each unsatisfactory state and the probability that the failure with the maximum severity would occur. These risk indicators can be used for various aspects such as water quantity and quality, crop area, yield or production, and flow requirement for environmental and ecological purposes. The selection depends on the specific analytical objectives.

Environmental System Integrity

A guiding criterion for sustainable irrigation water management is to minimize the interference of the irrigation system with the associated environmental system, including the effects on the water bodies that receive irrigation water through wind-drift, surface runoff, or drainage to groundwater. In addition, to sustain irrigation profit over the long term, irrigation water management must meet legislative requirements with respect to the environment. Indicators for environmental system integrity fall into three categories:

Health of aquatic and floodplain ecosystems

Extensive irrigation can affect drinking water health as indicated by bacteria, nutrients, and toxic contaminants, and soil health as indicated by the soil's water-holding capacity, total organic Nitrogen and Carbon, PH value, and the conditions of surface aggregates.

Water Quality

Irrigated agriculture affects water quality in several ways, including higher chemical- use rates associated with irrigated crop production, increased field salinity resulting from applied water, accelerated pollutant transport with drainage flows, groundwater degradation due to increased deep percolation to saline formations, and greater in stream pollutant concentrations due to flow depletion.

Soil Degradation

Irrigation is responsible for soil water logging and salinization in many regions where drainage systems are poor; irrigation with traditional furrow systems also causes soil erosion that can be measured by the extent of topsoil losses (Dinar, and Subramanian, 1997).

Thus, the adverse environmental effects of irrigation (such as water logging and salinization, groundwater pollution, and soil erosion) are often cumulative and may develop to an irreversible state because of long-term poor irrigation management. The measure of these indicators should be connected to both the short-term irrigation practices and performances and the long-term dynamic transmissions through some physical processes.

Equity

Equity is one of the basic concepts of sustainable development. Water is not just an economic resource; it is also a community resource with deep emotional and symbolic value. Experience has shown that plentiful and clean water flows toward the rich and powerful and away from the poor and powerless. Another emerging issue is the relationship between the environment and equity, which needs to better qualify the water needs of ecosystems and the economic, social, and cultural values, function, and services that aquatic ecosystems provide. Thus, equity in water resources management involves complex natural, political, and socioeconomic factors. The ASCE view of equity in sustainable water resources systems would allow people, "now and then" and "here and there" to share the water use right (both benefit and cost) in such a way that no one should be disadvantaged or inadequately compensated. Factors affecting temporal equity and spatial equity in water resources development can be either anthropogenic or natural, or both. Temporal equity is associated with resource depletion and long-term cumulative consequences that may lead to damages or even disasters in the future.

Spatial equity often concerns the conflict between upstream and downstream areas in a river basin and the conflict between various water users. As mentioned in the introduction, the continued availability of water for irrigation will be threatened in many regions by rapidly increasing nonagricultural water uses (in industry, households, and the environment), which normally have a higher marginal return than irrigation. The same conflict exists between farmers who plant high-valued crops and those who plant low-valued crops. Continued research is needed to measure the social value, or the public welfare component, of water to ensure that, when water is transferred, the area of origin will retain sufficient water to protect social value and to adequately compensate losses that cannot be prevented.

Moreover, water quality is also an equity issue. For example, conflicts arise when upstream users release excessive pollutants into the river and downstream users suffer damage resulting from the poor water quality. The measure of equity can be descriptive and normative. Descriptive measures simply evaluate the dispersion of the benefit using some descriptive statistic. Normative measures are derived from some underlying social welfare function.

Economic Acceptability

Besides food self-sufficiency, achieving net profit over the long term is the motivating factor that sustains irrigated agriculture. Economically acceptable irrigation systems provide lifestyle and social options for farmers and also contribute to the wider economy and community. From the perspective of using water more economically, the great challenge in irrigated agriculture is to include the opportunity costs of irrigation water supply, which are often an order of magnitude higher than current charges. Another challenge is to include the long-term economic damage to the environment due to irrigation. To maintain and improve economic acceptability, some regions will require investments both to enhance water supply capacity and to increase water use efficiency. Given all these considerations, the marginal benefit and marginal cost associated with irrigation development and management can be assessed. When the marginal benefit is less than the marginal cost, the irrigation practice loses its economic acceptability, which implies an unsustainable state.

Water Pricing in Irrigation

Universal access to water is one of the main challenges to sustainable development (SD) in the 21st Century. Therefore more effort is required to achieve the millennium development objectives (MDO) in water and sanitation sectors in order to provide sustainable services for all. The world environmental commission defined the concept of sustainable development as one which provides to the present without compromising the ability of future generations to provide for them. Despite the huge investments, the results are below the expectations due to institutional constraints and the burden of past policies and programs, which are heavily entrenched in every day practice of both decision makers and professionals as well. The development of the water sector was carried out unequally as it focused on drinking water and left sanitation behind and more on urban centers and less on rural areas, although some serious effort is being invested lately to bridge the gap. The main question is whether or not the management of the water sector is sustainable. Indeed, to be sustainable, management must consider the three pillars of:

(i) Irrigation financing and cost recovery
(ii) Management and cost recovery
(iii) Water pricing and economic incentives.

Irrigation Financing and Cost Recovery

Providing irrigation always entails a measure of human labor and capital investment. In traditional small scale systems investments were made by the communities themselves and the initial commitment generally defined rights to access water. Such undertakings were often limited (*e.g.* tapping a spring or a run-of-the-river diversion using a few stones or logs laid across a small stream) but could also be quite costly (as in the case of qanats, underground drainage galleries commonly dug over several kilo meters).

Larger scale ventures were financed directly by rulers (*e.g.* river diversions in Mesopotamia or large tanks in South Asia) who derived economic surpluses from the increased production. The view of irrigated agriculture as a means of ensuring both population needs and generating returns to capital was made explicit during colonial times. Investments in irrigation by the British in Sudan, Egypt, India and Sri Lanka for example, are all well documented, and income generation and profitability were central concerns. In Sri Lanka 'the English government was always concerned, and sometimes obsessed, by the protection and the increase of its income, as was the case in other colonial territory'. Colonial administrators sought both to protect and to uplift the poor masses, when considered to be in a state of misery, and involve them in productive capitalistic investments that would yield net revenues to the Crown .also documented the endless debates between supporters of irrigation and the guardians of the royal purse.

In contrast to narratives which assume that a focus on the economic value of water was characteristic of a late phase of water resources development, British colonial documents clearly show that most questions currently debated on the economics perhaps more accurately the financing of irrigation were already center stages. The questions of who was to finance the infrastructure (local revenue, the Crown, or private interests), whether and how a water fee should be levied, what its impact on different categories of people would be, whether it should be increased, whether it could influence crop choice or water use behavior, to cite a few examples, were fiercely debated. Opinions diverged between the British Government, the Government of India and other colonial authorities, local governments, canal engineers, etc., and alternatives such as private investments, bulk volumetric pricing and crop-based differential rates were all tested (Duane, 1986).

The financial or economic view of irrigation lost its prominence in the four decades following World War II. Irrigation and dams became pivotal investment options for developing countries, notably newly independent states, to deliver on the promise of feeding the masses, providing income opportunities to rural populations, balancing regional development and alleviating poverty and hence building self sufficiency and state legitimacy.

Development was seen largely as a matter of infrastructure and technical transfer, and large dams, irrigation schemes, flood control structures and other water projects received massive capital outlays. The national, as well as geopolitical, interests vested in such investments and in the increase in lending by development banks contributed to an outburst of projects, frequently undertaken on political rather than on sound economic grounds. Cost benefit analyses often remained shoddy and there was limited scrutiny on the assumptions and projections made. All parties involved (governments, local politicians, consultants, construction firms, lending agencies, etc.) had incentives to go ahead while the concerned populations were most of the time considered mere recipients of projects rather than partners in their own development. Whether politicians and engineers were infected by the 'desert bloom' syndrome ,fulfilled a 'hydraulic mission' through politically rewarding iconic mega projects or aimed to revitalize an impoverished countryside, free land and water resources were seen as the basic material of agricultural development.

These investments yielded mixed results. Although much was achieved, land productivity, distribution efficiency and management often remained suboptimal, economic returns were often disappointing and environmental externalities (salinization, water logging) became more evident with time. Technology alone proved unfit to deal with these growing challenges and attention shifted to organizational aspects, including farmers' participation, turnover and capacity-building. Initially, the World Bank funded only new projects, but poor performance led to a policy shift towards rehabilitation in the late 1960s. A first operational policy memorandum (OPM 2.61), issued in 1971, stated that the recovery of all project costs was a normal aim but offered a loophole by adding that 'as a minimum, operation and maintenance costs should be recovered completely'.

During the 1970s, the questions of why charge, and whom and how much to charge, for water stirred much debate at the World Bank. Proponents of irrigation lending and engineers perceived policy instructions as interference in their job. The prevailing philosophy remained that of 1971, though it was recognized that investment costs might be too high for beneficiaries to pay back and that a 'reasonable' share would be acceptable.

Covenant language was accordingly often vague 'to the extent practicable' or 'as much as possible' and there was virtually no capital cost recovery. An earlier study had shown that 17 projects completed in the 1960s had estimated levels of charge collection that exceeded operation and maintenance (O&M) but only amounted to 29% of full costs (Le Moigne *et al.,* 1994). In 1976, an 'informal discussion paper to assist staff in developing satisfactory approaches to cost recovery', followed by Central Projects Memorandum No. 8.4 by World Bank, defined new overall policy principles and guidelines, stressing three objectives as the basis for cost recovery: public savings, income distribution and economic efficiency. The objective of public savings was to 'enable governments to undertake additional rural development projects that would reach a larger number of the rural poor'.

It was also recognized that recovery of all costs might not be possible and that the poor should be identified and exempted. 'Efficiency pricing of irrigation water is usually not possible' but 'even a nominal price for water would offer users some incentive to eliminate at least some of the conspicuous waste and overwatering which occurs when water is treated as a free good'. Volumetric pricing was desirable but, if not practical, a benefit tax (linked to the land tax), 'although constrained by various administrative and political factors', should be considered a second best option.

In 1981, the Operations Evaluation Department (OED) released an analysis of 26 irrigation projects completed in the 1970s. Aside from severe problems with water management and maintenance, the survey found that cost recovery covenants had been breached in 11 cases, with no or limited water charges. Reasons included reluctance by government to reduce farm income, cultural or religious resistance, the political clout of farmers and a common 'operational' constraint: 'If project management cannot guarantee continuous and adequate water deliveries to most, or all, project beneficiaries, the Government becomes liable.' While, on the one hand, insufficient attention had been given to differing local conditions, on the other, large discrepancies in the way the Bank handled negotiations with different countries could not be explained by the policy guidelines. Lastly, no relation was found between charges and irrigation efficiency and 'factors, other than water charges, always proved to be much more import-ant in explaining farmer behavior than the presence, absence or absolute cost of water charges' (Rao, 1984). Application of the guidelines in different countries proved difficult. In Indonesia, reinvestment of charges in O&M was hindered by a fiscal problem of flow of funds between central, provincial and local governments, and the willingness to pay was affected by quality of service and by a taxation on rice amounting to 37% of the world price, in Bangladesh irrigation remained heavily subsidized with benefits accruing to the 'better off', in some countries studies on farmers' ability to pay were made at the Bank's insistence but their conclusions were disregarded.

The 1976 policy was broadened and simplified in a Policy Note, informed by yet another survey on cost recovery performance. This note distinguished between resource mobilization and allocation and emphasized again the failure to fund O&M, regardless of how much was recovered. It was proposed that assurances should be sought of adequate funds for O&M as a substitute for demanding cost recovery but this was edited out of the final text. The lack of incentive for non-autonomous agencies to collect fees or improve management, inadequate collection mechanisms and trans-action costs of collecting fees (especially if they were to be volumetric) were listed as constraints. Although the 'longer term objective to have a system of resource mobilization that will recover capital costs so permitting reliability of investments' remained, most Bank economists were incensed by the weakening of the principle of long term marginal cost pricing.

A further review of conditionality and cost recovery in 1986 confirmed that in only about 15% of irrigation projects were loan covenants fully met and that recovery rates ranged from 0% to 100% of O&M costs, with most in the range of 15-45%. Limited adherence to covenants was ascribed to:

(i) The lack of government commitment
(ii) Unreliable water supply due to poor O&M of irrigation systems
(iii) The often heavy burden of direct and indirect taxes already imposed on the farming sector.

The lack of relation between recovery and O&M effectiveness questioned the Bank's emphasis on cost recovery, the Bank's approach as 'heavily influenced by its thinking about authorities supplying public utilities such as electricity, water for domes-tic use, etc. which were expected to be self-sustained by commercial revenues' (Louw, and Kassier, 2002). The Bank policy had to come to terms with the fact that countries such as India or Thailand were clearly opposed to direct charges, either because irrigation was targeted towards the rural poor and was not expected to be self-sustaining or generate revenue, or because price distortions already siphoned off much of the agricultural surplus (Mexico, Thailand, Sri Lanka, Indonesia, Egypt, etc. In 1986, the Asian Development Bank (ADB) also carried out an evaluation of its irrigation projects and came to conclusions similar to those of the World Bank's 1981 review. In most cases, executing agencies had remained in complete or partial default of irrigation service fee covenants.

Management and Cost Recovery

Despite these disappointing reviews, 1986 was notable for a growing consensus that coalesced in a number of converging analyses of the role of irrigation service fees and their relationship to other mechanisms for improving irrigation performance. A World Bank study (World Bank, 1976) for instance, condensed ideas collected from a few country level analyses and concluded that 'it is time to take a more pragmatic and comprehensive approach to this. Although emphasis differed, there was general agreement that water charges alone were an inadequate mechanism for improving irrigation performance and that primacy needed to be given to water distribution and control. Staff members of development banks acknowledged that 'an element of subsidy in irrigation projects is not necessarily sub optimal' and that 'bidding for water should not be promoted'. The following list by and large summarizes this consensus:

The Primacy of Management

Irrigation water charges influence individual farmer behavior in only a very few on-demand systems. By far the most important mechanism for achieving rational water use is by careful control of distribution and by allocations that broadly meet crop requirements. Fee policies have little or no impact on irrigation system performance.

Control of Supply a Prerequisite

Many of the frequently cited inefficiencies of water use in irrigation projects stem more from inadequate control over the distribution of the supply of water than from failure to regulated demand through prices. Supply control can reduce wastage of water associated with excess amounts of water flowing through uncontrolled canals and ungated turnouts onto fields and into drainage channels. It may also encourage more efficient use of water at the farm level by imposing a degree of water scarcity on the farmers. A substantial portion of the large efficiency gains which are some-times expected from a demand based pricing system would thus most probably be realized by implementation of the prerequisite supply control.

Financial Autonomy

The way in which fees are assessed, collected and expended is more important than the actual level of fees in improving system efficiency and effectiveness. The most critical factor is the level of fiscal autonomy of the irrigation agency, *i.e.* the extent to which the level of its operating budget is tied to the amount of revenue generated by irrigation systems operations. This provides an incentive for cost effective goal oriented performance that is otherwise often weak or lacking.

Contextualized Cost Recovery

The principle of charging for water should be contextualized to consider ability to pay and the overall taxation of agriculture, indirect charges often providing an indirect (but straightforward) means to recover investment costs. Cost of collection needs to be evaluated carefully, price structures tailored to the particular situation and prices indexed. The evaluation of what should be the ideal level of O&M activities should receive more attention.

A Contribution Principle

Subsidized water users should repay some of the investments but they should not be asked to repay the cost of 'over elaborate gold plated designs, incompetent, expensive construction, cost overruns for reasons of corruption, bad scheduling of construction activities or the like, nor over manning of the public sector' (Chaudhry, 1993). While making farmers pay for O&M costs is achievable in most cases, in very few projects (if any) would farm revenues be enough to repay investment costs.

The exception to this consensus was discordant but influential paper on rent-seeking and the performance of public irrigation schemes, which heralded the coming critiques of the 1986 consensus. Convincingly showed how the design and development of irrigation projects were influenced by rent seeking strategies. From this, he concluded that there was little virtue in objectives other than economic viability, advocating that irrigation projects should be considered as normal investments requiring recovery of full costs, without considering secondary benefits. His analysis of pricing as a means to improve management, however, proved to be weaker: it shrugged off the constraints pointed to by the other studies and extrapolated particular cases, such as private irrigation schemes, to support the generalization of full volumetric pricing and the trading of water rights. Endorsed the model of financial autonomy but in the narrow sense of the utility model, without flagging the difficulties inherent in water allocation and distribution in large scale surface hydraulic systems.

Analysis coincided with a growing awareness in the 1980s and early 1990s in the wake of financial crises and structural adjustment programmers, of the burden on government finances inherited from ever expanding schemes of dubious profitability. Several countries including the Philippines, Mexico, Morocco, China and Turkey, opted for reforms primarily aimed at shifting part of the O&M burden to the farmers, blended with varying degrees of transfer of management responsibility. These experiences were sometimes influential but failed to launch a wider dynamic that would have embodied and imposed the principles identified.

At the Bank, the debate was not interrupted by the series of documents issued in the 1980s. The decade ended with a renewed attempt to clarify issues and break away from past confusion; several mistakes from the past were acknowledged *e.g.* 'zeal for the fiscal autonomy model' has been insensitive to borrowers' policies and the 'single minded application of the model (Cornish *et al*., 2004) to a second best world' might not be adequate; establishing boundaries between poor and other farmers to be charged is 'unworkable'. On the other hand, emphasis was put again on the priority to be given to physical sustainability, on accepting 'the diversity of cultures and institutional arrangements in borrowing countries' and on basing cost recovery policy on a full analysis of government interventions.

Water Pricing and Economic Incentives

Although the ideas can be traced back to earlier periods, 1992 marks a convenient turning point in the debate on water pricing: in 1992, the Dublin International Conference on Water and the Environment proposed a set of four principles, the fourth[9] of which underscored that 'managing water as an economic good is an important way of achieving efficient and equitable use, and of encouraging conservation and protection of water resources'. Although, as seen above, there was nothing novel in the concern with financial profit-ability, the fourth Dublin principle can be considered a landmark shift in emphasis to the economic dimensions of water use in general and irrigation development in particular. Economic instruments and the economic value of natural resources further found legitimacy in the Rio Declaration on Environment and Development of the United Nations in 1992 and its Agenda 21 which supported the 'implementation of allocation decisions through demand management, pricing mechanisms and regulatory measures'.

More generally, the early 1990s saw the rise of the concept of demand management (which can be defined by 'doing better with what we have' as opposed to continuous supply augmentation), mostly under the influence of resource economists stressing both the economic nonsense of privileging costly and environmentally unfriendly water resources development, and the role and potential of economic incentives in man-aging demand and reducing the need for additional supplies. The emphasis put on economic efficiency and on the 'user pay' and 'polluter pay' principles struck sensitive cords and ushered in heated debates on the right to water, the respective roles of the private sector and local communities, and how to interpret and reconcile the economic and socio cultural dimensions of water (Johansson, 2000).

Conceptually, this period distinguishes itself from the preceding one by a shift in emphasis, earlier justifications of charging for water centered on the financial need for cost recovery to fund further projects (equity) relieve state finances and ensure the physical integrity of, and continued benefits from, irrigation schemes. In the 1990s, water prices, and more generally economic incentives, came to be seen as key policy tools endowed with the potential to achieve multiple objectives. With demand management oriented approaches making conservation a critical issue, the conventional role of prices in managing demand moved from the back seat to center stage. Likewise, increasing intersect oral competition for water and associated environmental externalities made pricing mechanisms appear as a potential and desirable means to arbitrate water allocation and promote desirable environmental objectives, while maximizing water productivity and aggregate economic welfare. Assigning all these roles to pricing could be seen as the embodiment of the Dublin principle stressing the economic nature of water.

Given this anticipated potential for ensuring financial autonomy of the irrigation sector, cutting state expenditures, eliciting water savings and maximizing the economic efficiency of water use across society, water pricing understandingly attracted increasing attention from policy makers, academics, development agencies and banks. With so much frustration generated by the need for repeated rehabilitation (in Indonesia for example one third of the 3 million ha of government-designed irrigation schemes has been rehabilitated twice in the last 25 years by failed attempts to improve water management or efficiency substantially and by incomplete turnover of management to farmers, price instruments appeared to hold the promise of promoting several desired policy goals. In addition, they would pro-vide an elegant solution to long standing problems, changing behavior directly through incentives, thus seemingly avoiding the painstaking intricacies of irrigation management, and its technical, social and political ramifications (Tsur, and Dinar, 1995).

This economic rationale soon percolated to water policies. The World Bank's Water Resource Management Policy Paper of 1993observed that waste and inefficiencies have resulted from the frequent failure to use prices and other instruments to manage demand and guide allocation, and established a powerful narrative around the overarching causal link between water crises, water waste and under pricing. Subsequently, the Bank's policy paper remarked that the value of water differed greatly between agriculture and other sectors, often indicating gross misallocations if judged by economic criteria. It followed that 'setting prices at the right level is not enough; prices need to be paid if they are to enhance the efficient allocation of resources'. Besides continuing to ensure basic cost recovery, price mechanisms were thus assigned the further objectives of reducing water waste, minimizing environmental damage and reallocating water towards higher uses.

The 1990s saw a flourishing literature on the theoretical principles and potential impacts of pricing and water markets, with a leading contribution from the World Bank. During a press conference in Washington on 12 April 2000, President of the World Bank, reiterated the view that the biggest problem with water is the waste of water through lack of charging and saw water pricing as a primary means to improve water allocations and to encourage conservation. The Economic and Social Commission for Asia Pacific in its 1996 saw pricing as an essential component of water demand management, which could in particular significantly reduce the wastage of resources. ADB, in its 2000 water policy, reaffirmed that it needs to promote efficiencies in water use by supporting demand management, including water pricing. Finally, report proclaimed, that the single most immediate and important measure that we can recommend is the systematic adoption of full cost pricing for water services, although acknowledging that full cost pricing, long advocated in the irrigation sector has seldom happened (World Bank, 1986).

These views were consonant with, and perhaps partly derived from, policy shifts in developed countries. The late 1990s saw the gradual elaboration of the European Water Framework Directive which put economic incentives in general and pricing policies in particular at the heart of its objectives of financial and environmental sustainability. Interestingly, the use of pricing in the EU policy is advocated primarily as a conservational means to manage demand so as to curb excessive abstraction of water from ecosystems, and incorporates the polluter pay principle with water charges being instrumental in internalizing environmental costs. This reflects the weight of environmentalism in promoting economic incentives as key tools for water policy. In contrast, official references to the sectorial allocation and to charging opportunity costs are rare, although some environmentalists regard full cost pricing as a way of decreasing demand and environmental damage since, the price of water could be raised until the level of demand was consistent with the environmental constraints on supply and since, full cost recovery for water services should include the costs of damages to the environment. Numerous analysts have embraced the concept of demand management seeing its application as a primary means to solve the current water crisis. In turn, central ideas such as the persistence of massive water losses in the agriculture sector, poor management and misallocation of water resources, and the crucial role of economic incentives made their way into the mainstream media including (Svendsen, 1986).

These ideas trickled down to policy and law making in many countries. The 1998 South African Water Act specifies that water use charges are to be used to fund the direct and related costs of water resource management, development and use and may also be used to achieve an equitable and efficient allocation of water. Article 19 of the 1997 Brazilian water law recognizes water as an economic good and introduces water fees with the triple objective of indicating the value of water, rationalizing the use of water and levying funds for the further development of water resources. The 1999 National Water Policy of Bangladesh states that system of cost recovery, pricing and economic incentives/disincentives is necessary to balance the demand and supply of water and that water will be considered an economic resource and priced to convey its scarcity value to all users and provide motivation for its conservation. Many other state policies or legal acts include similar general principles or focus on particular ones such as cost recovery in the case of Vietnam users have a financial duty and the duty to contribute manpower and budget.

The apparent overwhelming adoption of pricing principles created an intellectual environment which made it somewhat difficult for alternative or nuanced voices to be heard. Several papers looking critically at the issue were published and several reviews were carried out though they did not significantly alter the debate on the World Bank and irrigation questioned the Bank's enthusiasm for irrigation cost recovery a presumed link between cost recovery and better operation and maintenance, because it confirmed earlier findings by OED that there is normally no link between higher water charges and better operation and maintenance. Revenue from water charges generally goes to the general treasury and is not earmarked for O&M.

Conclusions

Sustainable irrigation water management should simultaneously achieve two objectives: sustaining irrigated agriculture for food security and preserving the associated natural environment. A stable relationship should be maintained between these two objectives now and in the future, while potential conflicts between these objectives should be mitigated through appropriate irrigation practices. Sustainable irrigation water management should reach a two part objective, simultaneously sustaining both irrigated agriculture required for food security and associated environment. The way to achieve sustainability is to resolve the conflicts arising from the interactions between water use and the environment, and to balance the benefits between current and future generations. To achieve sustainability, decisions at all the various levels from crop field management to water allocation at the basin scale and agricultural policy at the regional and national scale must follow the newly developed sustainability principles.

To achieve sustainability, decisions at all the various levels from crop field management to water allocation at the basin scale and agricultural policy at the regional and national scale must follow the newly developed sustainability principles. The complexity involved in irrigation water management necessitates a systems approach to water management analysis. This approach translates broad guidelines for sustainable water resources management into operational concepts that can be applied to water management in irrigation-dominated river basins. Appropriate indicators are defined to measure sustainability, taking into account risk minimization in water supply, environmental conservation, equity in water allocation, and economic efficiency in water infrastructure development. Moreover, investments to improve infrastructure could be financed from taxes on increased profits resulting from the infrastructure improvements.

However, the taxation and investments will depend on the development of an interstate agreement on basin infrastructure investments. The complexity involved in irrigation water management necessitates a systems approach to water management analysis. This approach translates broad guidelines for sustainable water resources management into operational concepts that can be applied to water management in irrigation-dominated river basins. Appropriate indicators are defined to measure sustainability, taking into account risk minimization in water supply, environmental conservation, equity in water allocation, and economic efficiency in water infrastructure development.

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