Draft

Comprehensive Assessment of Socio-Economic Impacts of Agricultural Water Uses: Concepts, Approaches and Analytical Tools

Intizar Hussain

and

Madhusudan Bhattarai

Acknowledgements

This paper is a part of the work being carried out at the International Water Management Institute (IWMI) under tow of its multi-country projects: (a) comprehensive assessment of costs and benefits of agricultural water management, and (b) an ADB funded project on Pro-poor intervention strategies in irrigated agriculture in Asia.

Contents

Comprehensive Assessment of Socio-Economic Impacts of Agricultural Water Uses: Concepts, Approaches and Analytical Tools

1. Introduction

Irrigated agriculture has expanded enormously over the past five decades—resulting from a revolution in irrigation development—which has increased from less than 100 million ha in 1950 to more than 275 million ha in 2000. Most of the expansion in irrigated area during the period has taken place in developing countries. Out of total global irrigated cropland, nearly 100 million ha is in China and India, which constitutes more than one third of the total irrigated land globally. Massive expansion in the irrigated area in the 1950s and 1960s in Asia is considered to be the backbone for the success of the Asian Green Revolution in the 1970s and thereafter. Despite the significant contribution of irrigated agriculture to increasing food production and to overall socio-economic development, irrigation has come under increasing criticism over the past decade—for concerns such as socio-economic inequity, social disruptions and environmental changes that are attributed to irrigation development and reservoir construction.

Expansion in surface irrigation water supplies, with construction of new dams and canals, has been accompanied by substantial increases in groundwater extractions. While these irrigation developments have provided substantial benefits (increased food production, food security, labor price etc.,), they have also imposed significant costs on society. In general, if aggregate benefits of irrigation at the society level outweighed aggregate costs, nations have done well. However, if costs outweighed benefits, this raises serious concerns about past investments and provides lessons for future irrigation development. While there is a dearth of assessment of benefits and costs of irrigation, the available past work is more micro focused and is highly partial. These partial assessments have been based on only a few direct benefits and costs and have largely ignored many indirect benefits and costs of irrigation. In irrigation project proposals and related feasibility studies, benefits of irrigation are often overestimated in order to get the projects approved. Post-project evaluations of a large majority of irrigation projects suggest that their economic performance have been low compared to pre-project predictions. This is also due to the fact that in most of these projects, social and environmental concerns have not been fully incorporated.

Increasing environmental problems associated with irrigation development and management has led to a controversial debate on the impacts of irrigation. Proponents argue that irrigation has contributed substantially to increased food production and that further expansion in irrigation would be essential to meet increasing food needs of rapidly growing populations, while opponents argue for contraction in irrigation to reduce its negative effects on the environment, and also for reallocating more water for

environmental needs. Often, these arguments are based on extreme situations—where irrigation has provided enormous benefits, and where it has resulted in substantial costs including indirect costs to societies and nations. Inadequate information on estimates of the full range of costs and benefits and the overall impacts of irrigation has been a major constraint in resolving this controversy. This is due to inadequacy of existing valuation methods and tools and their applications in generating such information. Partly, this is due to complexities of irrigation impacts, and the vast scale of externalities involved. This paper provides a methodological framework on comprehensive assessments of socio-economic impacts (costs and benefits), and the complexities involved in assessing irrigation impacts in a real world situation. The material in this paper is expected to be useful to water policy impact analysts for carrying out detailed analyses, and for applied empirical analysts in the water sector.

2. Objectives and Scope

The major objective of this paper is to provide a conceptual framework and issues involved in *ex post* comprehensive assessments of the full range of costs and benefits of agricultural water resources development and management. While the primary focus of the paper is to provide a generic framework for impact assessment of irrigation development, the discussions here also includes assessment of impacts on non-agricultural sectors using water from irrigation infrastructure or are impacted by irrigation development. The specific objectives of the paper are: 1) to illustrate the conceptual framework for impact assessment of irrigation development; 2) to describe potential economic approaches that can be adopted to undertake comprehensive assessments of costs and benefits ; 3) to discuss some of the methods and analytical tools for assessing the impacts.

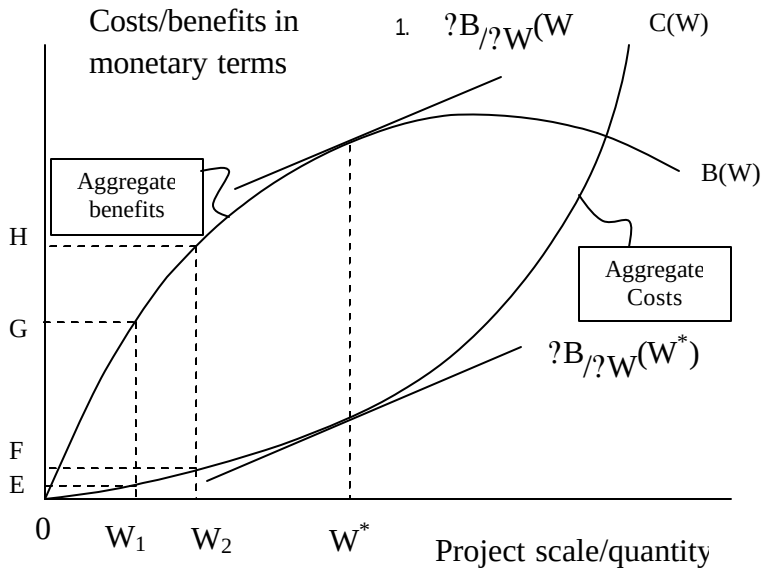
The process and analytical tools for impact analysis at aggregate level differ from that of the irrigation project command or farm-level impact assessment. With a brief overview of aggregate level impacts, the discussions in the paper focus more on the irrigation project level impact assessment. It should be noted that the specific methodology and the analytical tools used for assessing irrigation impacts largely depend upon the local context and the type and nature of characteristics of irrigation impacts to be evaluated. There is no universal type of one-menu-fit-for-all type of irrigation impact assessment methodology. The purpose of this paper is to present a generic framework and to highlight some of the common issues involved, based on a review of recent literature on impact assessments. Improved understanding of impact assessment is particularly important in view of increasing global policy debates and concerns on efficacy and performance of irrigation in the past.

3. Conceptual Framework for Impact Assessment—Approaches and Issues

Every choice in a society has an underlying economic dimension—do the benefits exceed the costs of that particular choice? Assessments of benefits and costs for any resource in a comprehensive and systematic framework deals with evaluating the economic worth or desirability of options and assists in decision making about competing alternatives. Water

is a scare resource. Water resources development and allocations under growing competition and increasing scarcity involve decisions on competing alternatives for investment funds and for use of water among various sectors. The tradeoff in resources use is the central concept of economic efficiency—which is defined as allocation of resources so that no further reallocation would make anyone in society better-off without making some one worse-off. This is generally referred to as the Pareto optimality state—economic welfare maximized. Pareto optimality occurs when marginal benefit of a resource is equal to the marginal cost of supplying the resource. While theoretically attractive, hardly any practical policy change would meet the Pareto optimality criteria. However, welfare theorists bypassed this strict criteria with a compensation test, i.e., if gainers could in principle compensate losers, the change would be acceptable whether or not the actual compensation takes place—this is generally referred to as the potential Pareto improvement (Randall 1987). Any action or policy change, which generates incremental benefits in excess of incremental costs, would be Pareto superior as it would lead to a superior condition to status quo. This concept is clearly depicted in figure 1 below.

Figure 1. Relationship between cost-benefits analysis and resource use efficiency (Based on Young 1996).



An example of potential Pareto improvement and its relationships in cost-benefit analysis would make these concepts more clear. In figure 1, the curves B(w) and C(w) represent aggregate benefits and costs, respectively, associated with alternative scale of a water development project. The assumptions here are that benefits increase as the scale increases but at a decreasing rate and that cost increases at an increasing rate. The Pareto efficient or optimum solution, i.e., where the most efficient resource allocation occurs is at W^* where marginal benefit is equal to marginal cost. At W*, we have the condition that $?B_{/?W}(W^*) = ?C_{/?W}(W^*)$, i.e., the slope of the B(w) curve is equal to the slope of the C(w) curve. However, in a real world situation cost-benefit analysis and aggregated incremental benefits (IB) are compared with aggregated incremental costs (IC), and if the former exceeds the latter, the policy change is considered to be desirable—a Pareto improvement. Any shift from 0 to W_1 to W_2 to W* would be a desirable shift as it would lead to more and more and the most efficient reallocation of resources. Beyond W*, the net benefits are still positive but are at a decreasing rate. The net benefits are zero where the benefit and cost curves intersect and are negative beyond the intersection point.

This is what is accomplished through the cost-benefit analysis (CBA) approach. Conventional CBA compares the present value of all current and future costs and benefits of a policy action—and the amount by which benefits exceed costs. Society benefits in economic terms as a result of this policy change. Is CBA a suitable approach for comprehensive assessments of costs and benefits of past irrigation developments? Following are some of the major concerns on application of conventional CBA in irrigation impact assessment .

1). Typically in CBA, estimates and comparisons of costs and benefits are limited to directly affected sectors, and the economic impacts on other sectors of the economy generally fall outside the scope of CBA, with the assumption that other markets in an economy are either unaffected or unimportant for net benefit estimations. However, it can be argued that large-scale irrigation developments can have significant impacts on other sectors in an economy. Irrigation projects are usually initiated with broader socio-economic and regional development goals than mere financial gains or efficiency targets.

Economic Impact Assessment, which is much broader in scope than CBA, accounts for sectoral linkages including the impacts in secondary and tertiary markets. Analysis of impacts such as changes in productivity, changes in prices resulting from shifts in supply and demand, and changes in macroeconomic variables (such as employment, trade and exchange rates) can be incorporated in an economic impact assessment approach. These macroeconomic impacts can be modeled either through partial equilibrium approaches (such as econometric modeling) accounting for a few important sectors. Or, it can be done through general equilibrium approaches, such as by using input-output (I-O) models, social accounting matrix (SAM), or computable general equilibrium (CGE) analyses. In I-O and SAM models, linkages among various sectors are established by constructing input-output matrixes, and input-output relationships are quantified through multipliers. The magnitude of these multipliers indicates the extent of impact of one sector on others, including direct and indirect impacts. However, IO models are deterministic in nature and they do not capture societal (agent's) optimizing behavior

based upon some equilibrium concept, nor do these deterministic models capture changes in economic surplus (changes in the value of resources). Unlike I-O models, CGE models incorporates more realistic market behaviors. While both I-O and CGE models are useful tools, data and time requirements for developing these models are enormous, which are the major limitations for application of these models in small-scale assessment exercises.

2) CBA deals mainly with economic efficiency or gains from a policy change, it typically does not account for distributional impacts of a project, or equity and other related social issues. In reality, irrigation development may have serious consequences in terms of distribution of gains (among rich and poor), inter-regional impacts (upstream-downstream impacts) and inter-generational equity impacts, these distributional consequences of irrigation cannot be ignored. Sometimes, it is suggested that in order to incorporate equity issues, standard CBA be adjusted using distributional weights[1], i.e., treating different groups differently by using weights (more weights to benefits and costs for poor and less for rich). However, determination of weights is highly complicated, and more often the weights are highly subjective in nature depending upon socio-economic and political development goals. In the absence of objective methods of determining weights and the amount of information required to undertake distributionally weighted CBA (DWCBA), its practical application remains very limited. Also, there are other social impacts of irrigation that cannot be monetized (such as loss of cultural heritage or historical places as a result of irrigation development), which generally fall outside the scope of CBA. To account for these and other types of impacts, it is suggested to carryout a full social impact assessment—which should account for all the quantitative as well as qualitative aspects of the social impacts of irrigation.

3) CBA accounts for only those impacts that can be quantified in monetary value terms and are traded in the market place. However, monetization is a major problem for many environmental impacts related to water resources. Regardless of whether the impacts can be monetized, these should be included in assessments, particularly all major social and environmental effects. For the environmental impacts, there is a need to undertake a full environmental impact assessment (EIA) to account for all the quantitative as well as qualitative aspects of the environmental impacts of irrigation. Analytical tools like, multi-criteria analysis and multi-objectives planning are emerging as important tools to incorporate less quantifiable and non-monetizable factors into basic CBA framework, which also include political and broad social objectives in the project planning process.

In sum, it is suggested that while CBA can be used as a basic approach for impact assessment, it should be supplemented with additional analyses through full economic, social and environmental impact assessments[2]. It should be emphasized here that in *ex post* impact assessments, the view point taken should be of the society as a whole (i.e., country), and all the outcomes and impacts of irrigation that change the net benefits to society should be included in assessments.

---

[1] These distributional weights are determined by policy makers and politicians based on societal goals.
[2] The focus of this paper is on valuation of socio-economic impacts of irrigations systems (projects). Detailed discussions on environmental and ecological impacts of irrigation can be found in environment impact assessment literature.

Realizing these limitations of CBA and the controversies brought on by large-scale water resources development projects, the World Commission on Dams (WCD) has recently undertaken a comprehensive review of economic approaches and their limitations for assessment of impacts of large dams (WCD 2000). The WCD extensively reviewed limitations of the CBA approach in water resources development projects, including valuation of externalities, distribution issues and risk and uncertainty. The WCD review expert panel recommends "a comprehensive basic cost-benefit should be undertaken of costs and benefits (both external and internal) attributable to a project whose values can be expressed, in generally acceptable monetary terms. Other (non-monetizable) elements should be integrated with the results of the CBA in a multi-criteria analysis." The commission emphasized five core values or key criteria to be taken for options assessment, or project evaluation, of any large dam project. They are: *equity*, *efficiency*, *sustainability*, *participatory decision-making*, *accountability* and "*rights and risk*." All of these criteria (some of them are more subjective in nature) are difficult to include within the framework of CBA in a single case study. These criteria, however, still remain untested in water project evaluations and impact assessments. To the best of our knowledge, there is no study available incorporating all these five criteria in a single project evaluation process.

Incorporating Environmental Concerns in Costs Benefits Analysis and Impact Assessments

The basic notion of cost benefits analysis (CBA) of a project, as described in the earlier section, is to compare the estimated costs against predicted benefits that are likely to be generated through the investment. The basic criteria of the CBA are that the net present value (NPV), after subtracting discounted costs from the discounted benefits, should be positive. That is:

$$NPV = \sum_{t=0}^{T} \left[\frac{B_t - C_t}{(1+r)^t} \right] > 0 \qquad (1)$$

Where: B_t = *Irrigation project incremental benefits*

C_t = *Irrigation* project incremental costs (1)

r = project discounting factor (interest rate)

t = project life span, t = 0.....T

In equation 1, we can also include the components of environmental costs (as well as social costs), or the costs related to environmental externalities that can be properly identified, quantified, and valued in monetary terms, thereby extending the domain of the cost-benefits framework a little further as:

$$NPV^{E} = \sum_{t=0}^{T} \left(\frac{B_t - C_t - E_t}{(1+r)^t} \right) \geq 0 \qquad (2)$$

Where:

E_t = *Environmental costs (benefits) also called externality factor*. This can be negative for the net environmental adverse effects and positive for the net environmental favourable effects.

B_t, C_t, r_t *and* t are same as explained above.

Here, E_t is negative if there is a net environmental (or social) cost associated with the irrigation project and E_t is positive if there is a net environmental (social) benefit from irrigation development after subtraction of negative environmental effects. In the real world context, proper valuation of this E_t component of equation 2 is one of the most difficult parts of the irrigation impact assessment exercise. Moreover, not all professions (economists, engineers, ecologist, sociologist, environmentalists, etc.) agree on a common framework with uniform criteria and a common measure for E_t. For environmental and ecological functions, the concept of valuation differs among the professions, and the issue of valuing environmental impacts remains one of the most complicated and debatable issues in impact assessment process.

Impact Assessment and Integrated Water Resource Management (IWRM)

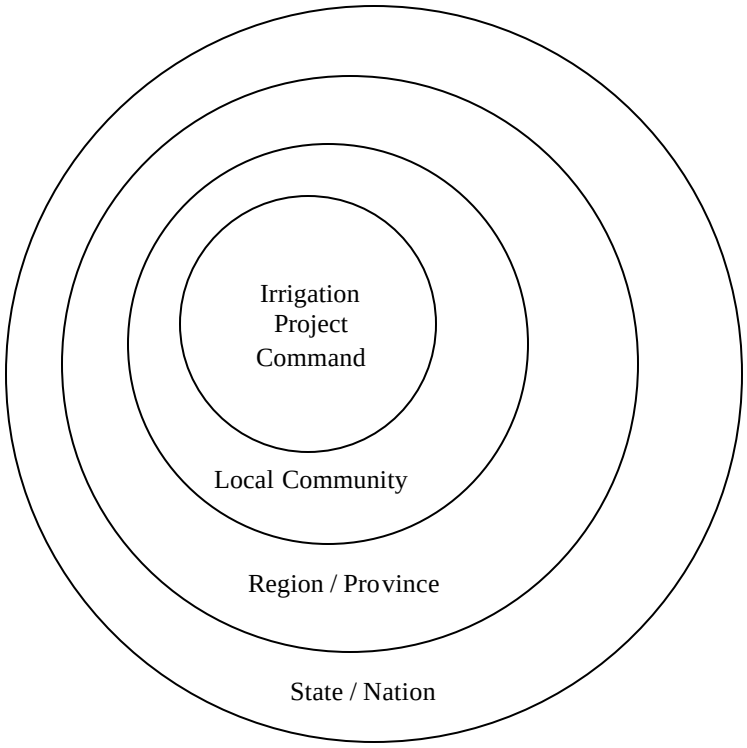
The comprehensive assessment of irrigation can also be looked at within the framework of integrated water resources management (IWRM), recently recognized as a necessary tool for efficient and effective use of water resources in a society. The Global Water Partnership in its *Framework for Action* (2000) argues that currently unsustainable management practices must be replaced by a holistic approach based on the concept of IWRM. IWRM is seen as the means of providing water security, of creating sustainable water policies and practices and of averting the risks to the global water system. There are three fundamental components of IWRM that take account of economic, social and natural conditions: (1) Economic efficiency in water use—using water with maximum possible efficiency; (2) Equity- equity in access to water of adequate quantity and quality for the sustenance of human well-being and (3) Environmental and ecological sustainability—managing water in a way that does not undermine the life-support system thereby compromising use by future generations of the same resource (GWP 2000). The IWRM framework and approach recognize that complementary elements of an effective water resources management system must be developed and strengthened concurrently. These complementary elements include: (a) the enabling environment—the general framework of national policies, legislation and regulations and information for water resources management stakeholders; (b) the institutional roles and functions of the various administrative levels and stakeholders; and (c) the management instruments, including operational instruments for effective regulation, monitoring and enforcement that enable the decision-makers to make informed choices between alternative actions. These choices need to be based on agreed policies, available resources, environmental impacts and social and economic consequences. Impact assessment under IWRM principles is much broader than simply economic or engineering efficiency criteria. The

impact assessment framework developed in this paper also includes some of the main components of IWRM, including inter-sectoral linkages.

Scale Issues in Impact Assessment

It has been widely recognized that development of agricultural water resources bring significant changes at various levels, from farm to national levels. These include changes in production patterns, land and property values, expansion in the use of complementary inputs (such as high yielding variety seeds, fertilizers, pesticides, etc.), and expansion in overall economic activities through backward and forward linkages. The impacts of these changes vary greatly from one level to another. Some of the impacts are confined to only farm level, while others spread to the whole project command and others spread to wider region and province/state or national level.

Figure 2. Scale of Impacts generated by an irrigation project.



Thus, the nature of irrigation impacts depends upon the nature and size of the project. The scale of impacts of irrigation development/management is depicted in figure 2. In

general, the wider the project effects are, the more difficult it is to assess the impacts accurately. The primary or the immediate impacts are relatively easier to evaluate in monetary terms. The secondary impacts, which are important in irrigation decision making for regional employment, for regional food security and poverty alleviation are relatively harder to assess in monetary terms. As the scale of the project expands, secondary impacts of irrigation also get amplified, resulting in more complexities in the impact assessment exercise. For impact assessment, the impacts may be classified according to the following scales:

1) Farm level impacts
2) Project command or system level impacts
3) River basin level impacts
4) Regional or province level aggregate impacts
5) State and national level aggregate impacts

The specific methods and/or analytical techniques for assessing impacts will vary by the scale of impacts being evaluated, and the nature and objectives of impact assessment. For example, the aggregate impact assessment task is done more at wider level but with limited variables and for few issues (mostly for economic impacts) using the secondary aggregate level information. The project or farm level assessments are more detailed (and include aspects which are difficult to deal with at the aggregate levels or the higher scale) and provide more reliable information. For example, the environmental and ecosystem impacts, which have spatial dimensions and tend to be more localized, can be relatively easily evaluated at the lower scale than at the higher scale. In the following section we present separate frameworks for project level and aggregate or national level assessments. But before we go into the details, let us briefly look at the various uses and key potential impacts of irrigation.

4. Uses and Impacts of Irrigation Water

Irrigation impacts may vary considerably depending on the source of water, river diversion project or from large reservoir or groundwater based irrigation. Groundwater is mainly used for local level crop production and municipal uses. However, surface irrigation infrastructure provides water for a variety of uses with wider area coverage, with potential impacts and likelihood of associated externalities greater than that from groundwater use. Therefore, discussions in this paper are mostly related to surface water sources of irrigation projects. Water uses from surface irrigation water can be classified as follows:

A. Withdrawal uses
   - ? Irrigated agriculture
   - ? Urban domestic uses
   - ? Commercial and industrial uses
   - ? Rural domestic and livestock, and rural small-scale enterprises

B. In-stream uses
   - ? Commercial/recreational fish production
   - ? Hydropower generation
   - ? Water transportation
   - ? Recreational uses of river flows, swimming, river rafting, etc.
   - ? Ecological uses, aquatic ecosystem protection, landscape view, etc.
   - ? Religious use of river, bathing, etc.

Impacts/Outcomes of Irrigation Water Uses

In most of the above uses, irrigation water has multiple effects (for details on multiple uses of water see, Baker et al. 1998). Some of the irrigation induced impacts are desirable and beneficial to society while others are undesired and adverse in terms of their negative impacts on humans and environment (ecosystems). Some of the impacts are significant, while others may be insignificant—some of them are known while others remain unknown. Some of the impacts are common to most irrigation development projects, while others are more specific to certain locations, schemes or methods of irrigation. These impacts may be broadly classified into desired impacts (benefits) and undesired or negative impacts (costs)

In a project level comprehensive assessment of irrigation impacts, following major impacts, both positive and negative impacts, can be identified.

A. Major Positive Impacts

(I) direct positive impacts of irrigation include:

1. Increased agricultural production
   - ? Increased crop productivity
   - ? Expansion in crop areas
   - ? Increase in cropping intensity
   - ? Increase in crop diversification
2. Increased commercial fish production (in-land fisheries)
3. Increased benefits of water use in industrial, commercial and residential sectors—from raw water provided through irrigation infrastructure or from groundwater
4. Increased environmental benefits of water for in-stream flows, disposal of waste, wildlife, flora and fauna; increased farm forestry and vegetation in irrigated areas.
5. Increased health benefits—improved sanitation due to better access to water.
6. Other direct positive impacts
   - ? Increased benefits from flood control
   - ? Increased benefits from water use for rural domestic and livestock purposes
   - ? Increased groundwater recharge; reduction in opportunity costs of water uses
   - ? Increased recreation from water bodies, sight seeing, fishing

(II) Secondary Impacts of Irrigation

? Increased employment in agriculture due to increased cropping intensity, increased crop area and output from irrigation
? Increased employment outside agriculture from increased crop output in related industries such as input industry (backward linkages) and output processing industries (forward linkages)
? Positive impact on poverty reduction through increased productivity and increased employment opportunities
? Increased food security at national, regional and local levels
? Lower food prices for consumers, due to productivity gains and increased overall food supplies
? Improved nutrition, improved calorie intake and improved health

B. Major Negative Impacts

Irrigation may have several potential negative impacts on agro-,eco- and human systems. These impacts may be also broadly divided into three categories:

? Adverse economic impacts: Higher subsidy, distorted market and a relative neglect of rainfed farming and other less favored farming practices
? Adverse social impacts: Forced displacement and involuntarily resettlement of the local inhabitants
? Adverse environmental impacts: Loss of biodiversity, obstruction on natural hydrological flows and damages to aquatic ecosystems

Some of the impacts are direct and enter into normal market process, whereas other negative impacts may be indirect and their costs may not be accounted for by individual decision-makers, nor are these costs are captured into the normal marketing activities—they are called as "externality effects." The term "externality" is generally defined as an effect or outcome when production or consumption of one party affects the production or consumption of another party and neither party makes any compensation for the effect. For example, costs imposed on downstream users of irrigated water polluted by upstream users. These are costs imposed on a society as a result of an action—irrigation development in this case. Based on the nature of the impacts on the surrounding environment and the changes they will bring in the hydrology and in the surrounding regions, environmental impacts or externalities generated by irrigation can be broadly grouped into three categories. They are:

? Change in water quantity: This is related to where water goes and how it is used, e.g., localized scarcity, water stress, etc.
? Change in water quality: This is related to change in quality and usability of water, e.g., water contamination, salt loading, etc.
? Change in soil quality: This is related to impacts of water uses on land fertility and changes in land quality, e.g., salinity build up, impacts on soil quality by changes in the water table, etc.

Some of the potential negative externalities associated with irrigation may include the following:

1. irrigation-induced land degradation
   - ? Soil salinity and water logging—on-farm and off-farm impacts
   - ? Loss of soil fertility due to irrigation induced crop intensification
   - ? Increase in biological imbalances due to irrigation (weeds, pests)
2. Surface water pollution—nutrients/chemicals
3. Groundwater pollution—nutrients/chemicals
4. Toxic concentration of substances in surface and groundwater—salts, metals and pesticides
5. Saline return flows
6. Health impacts in terms of increased water borne diseases (schistosomiasis, malaria)
7. Loss of bio-diversity—birds, fish and other wildlife species extinction
8. Negative impacts on wetlands
9. Social impacts
   - ? Communities displaced by large scale irrigation development
   - ? Loss of cultural heritage and historical places
   - ? Displacement of unskilled labor in mechanized irrigation

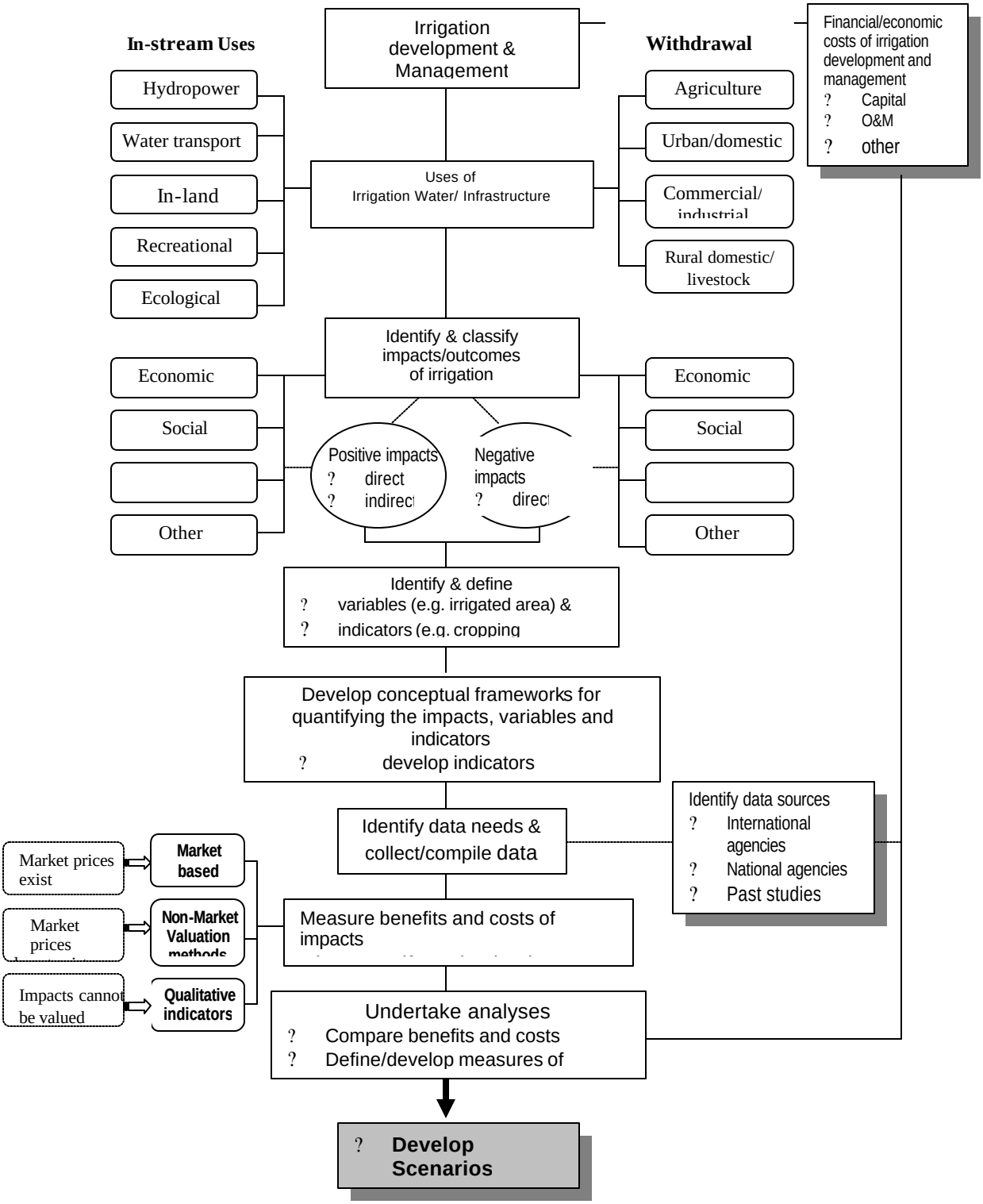
Given the wide range of these impacts, it may be useful to identify the causal factors for these impacts i.e. whether the impacts are due to farm level agricultural practices, field level water application systems, water distribution systems, water supply or drainage systems or large reservoirs or tanks.

5. Comprehensive Assessment of Irrigation Impacts—System or Project Level

The overall framework for comprehensive assessment of irrigation impacts at project or system level is outlined in figure 3, which indicates the steps required for assessing all the impacts associated with the irrigation development, and the complexities involved.

There are several logical steps to follow in order to identify various activities and methodologies. As is clear from the above discussion and the outline in figure 2, there is no single method or model that can be readily adopted to assess economic impacts or costs and benefits of irrigation. A range of methods, models or measures is needed in impact assessment exercise. In some cases, simple variables (such as irrigated crop areas) or combination of variables to develop indicators (such as cropping intensity, crop value) would be sufficient to measure the impact of irrigation. In other cases, modeling may need to be undertaken (e.g. estimation of production functions, impacts of irrigation on poverty or trade, etc.) and the modeling output could then be used to develop impact variables or indicators. An effort is made here to identify methods to quantify and value the impacts of key irrigation indicators in economic term. While it is recognized that some of the indicators would be difficult to value in monetary terms, monetized indicators would allow direct comparisons of costs and benefits. Valuation of all of these impacts would be an important component of the whole exercise of comprehensive impact assessment.

Figure 3: Broad framework for comprehensive assessment of irrigation impact at project level.

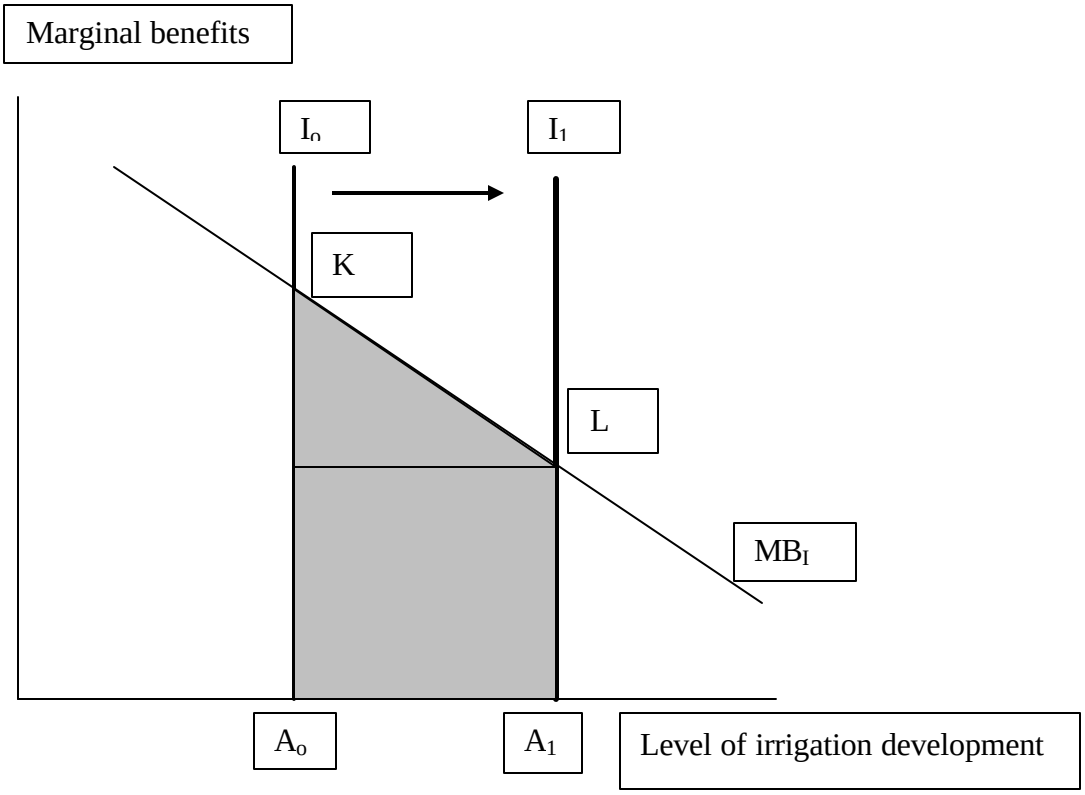


6. Irrigation Impacts Assessment at Aggregate Level

Unlike at the irrigation system or project level, impact assessment at the aggregate level is a little tricky as it requires certain specialized techniques and methods. Comprehensive assessment and evaluation of all the impacts generated by irrigation may not be feasible at the aggregate level. Impact assessment at the aggregate level is more suitable for assessment of mostly economic effects, because of the ready availability of regional or provincial level secondary information on economic and financial variables and indicators. Data on most societal and environmental variables and indicators are rarely available at regional or provincial levels, because of regional heterogeneity and aggregation issues (partially resulting from lack of appropriate methodologies for doing such aggregation of environmental and social factors). Some of the concepts, issues and methods required to carry out an aggregate level economic assessment of irrigation impacts are summarized below.

At the aggregate level, impacts of irrigation in a region or state can be measured by estimating changes in economic surplus brought by irrigation development, under the framework of consumer-producer surplus analysis. Under this framework, irrigation development can be hypothesized to bring a downward shift in the supply function resulting from increased production of commodities in the economy. The shaded area in figure 4 represents the net gains to society from the expansion of irrigation from I_0 to I_1. Marginal benefits to society from this expansion may decrease as irrigation expands, but the total gains at aggregate level will still be substantially higher depending upon the shape of marginal cost curve (or supply curve) of providing incremental irrigation (therefore we also need to have some information on the cost of providing of water services for impact assessment).

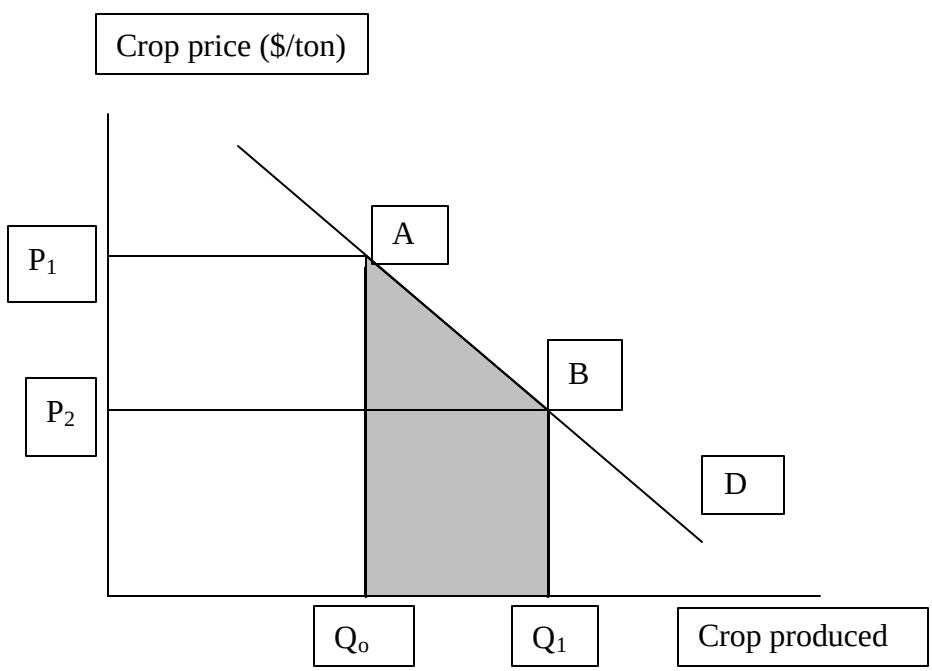
Figure 4. Total change in economic surplus due to irrigation development.



In figure 4, the MB_I curve represents consumers' (farmers') demand curve for irrigation at any point in time , which is also called farmers' marginal benefits function for irrigation, or marginal value product (MVP) curve of irrigation. The negative slope of the MB_I curve indicates that marginal benefits from irrigation decrease as the level of irrigation increases. This also means declining willingness to pay for a commodity by society at its increasing amounts. When irrigation development expands, say from I_o to I_1 (with a corresponding irrigated area expansion from A_o to A_1), the net change in economic surplus due to irrigation expansion is the shaded area of the trapezoid, KLA_1A_o. The change in economic surplus, area KLA_1A_o, is the total economic benefit to society brought about by the expansion of irrigation from I_0 to I_1. In principle, to undertake a comprehensive assessment of economic impacts of the area KLA_1A_o (benefits of irrigation) needs to be compared against the total costs of irrigation (including economic, social and environmental costs).

The change in economic surplus and its implications for valuation of benefits of water use (irrigation development) can be better explained by the products' demand curve. Figure 5 shows that as the level of crop production expands from Q_0 to Q_1 due to expansion of irrigation, the marginal price of the crop decreases, resulting in lowering farmers incomes[3].

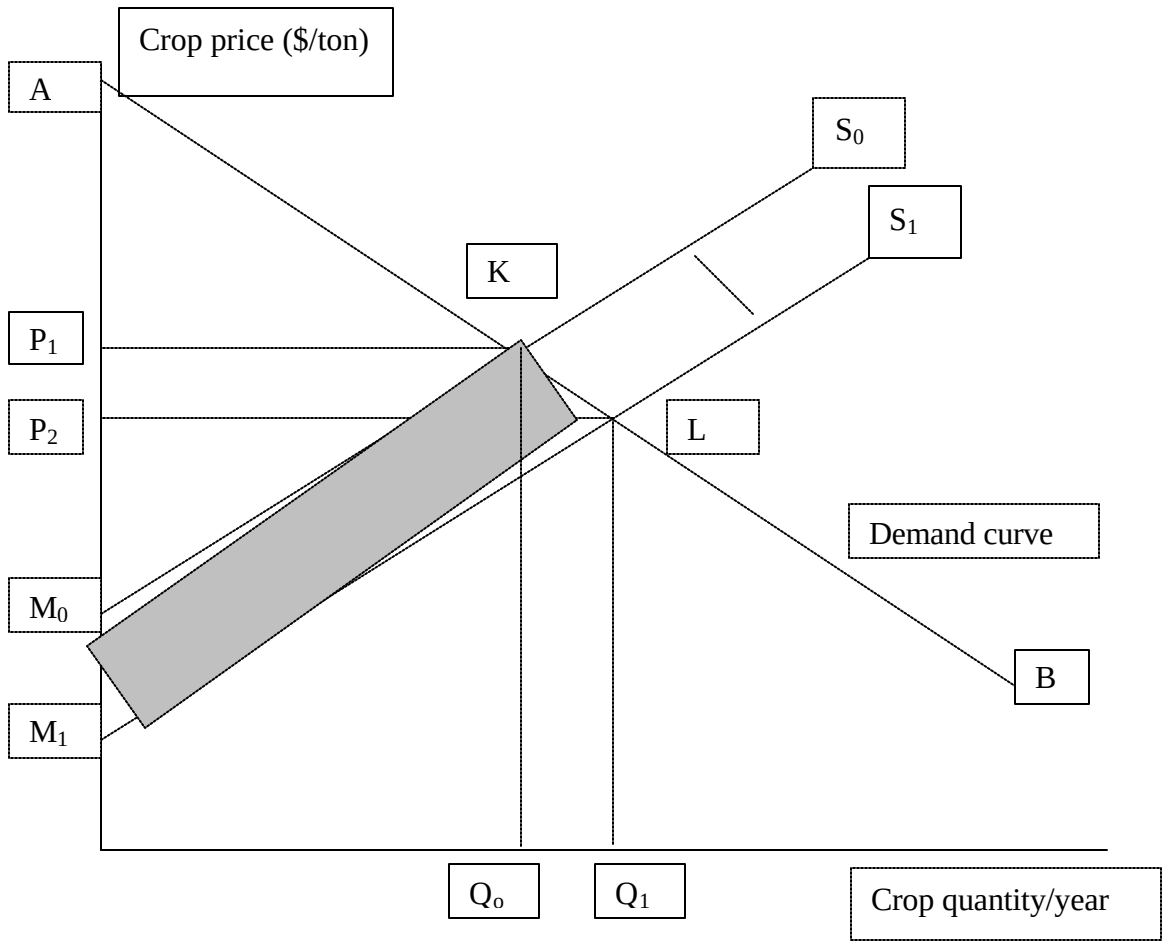
Figure 5. Irrigation impacts on increased crop production and decrease in crop prices.



[3] The decreasing trend of world food prices in the recent past has shifted public sector irrigation investment decision criteria from the objectives of increasing food production and maintaining national food security to objectives such as employment generation, regional development, poverty alleviation, maintaining rural livelihoods, etc. (note: the world market real price of rice in 2000 was less than 20 percent of what it was in late the 1970s). In addition, the gains to farmers (producers) and to the consumers (wider section of society including urban consumers) have also changed over the time due to changes in crops prices and factor prices.

The changes in the economic surplus due to a downward shift of the supply curve of the food grains (crops production) in figure 5 can be divided into two parts—one part is a change in consumer surplus (area above the price line and below the demand curve) and the other part is a change in producer surplus (area above the supply curve and below the price line). The change in the consumer surplus and producer surplus due to the supply shift (downward) is depicted in figure 6.

Figure 6. Change in economic surplus (producer surplus and consumer surplus) due to supply shift from irrigation expansion.



In figure 6, the area P_0KLP_1 is the change in consumer surplus[4], and the area (? P_1LM_1- ? P_0KM_0) is the change in producer surplus brought by improvement in irrigation. The consumers always gains from lowered commodity prices due to the expanded supply of commodities (foods) in the market. However, we cannot definitely say whether producers will also always gain from the supply shift. The level of producers' gain associated with the supply shift resulting from technological and infrastructural improvement (from S_0 to S_1 in figure 6) actually depends upon the elasticity of the demand and supply curves, the nature and magnitude of shifts in supply and demand curves and the producer's risk attitude towards the production process. The regression analysis allows us to estimate the

[4] The term economic surplus includes both producer surplus and consumer surplus as shown in figure 6.

supply and demand elasticities for commodities and to isolate the net impacts of irrigation changes in supply shift from other competing factors. Estimated elasticities can then be used to derive changes in consumer and producer surplus.

7. Quantification of the Impacts

After identifying all the relevant important impacts (based on inputs from a multidisciplinary team of experts), the next step would be to quantify them in physical terms. The purpose here is to quantify those impacts that arise with the introduction of irrigation or improved access to irrigation. There may be several different ways to quantify these impacts. Two commonly used approaches are (a) "before and after" comparisons; and (b) "with and without" comparisons. One of the problems with the "before and after" comparison approach is that it fails to account for changes in production that would occur without the project that could lead to erroneous estimates of the quantified impacts (for details see Gittinger 1982). Although the "with and without" approach also suffers from similar limitations, it is commonly used in real world impact assessments. It is suggested that, where data are available, both approaches should be adopted to gain more insights into the impacts. In this paper, we focus on the "with and without" approach considering the fact that in most cases data before intervention are rarely available.

With and Without Principle

The impacts of irrigation can be measured as the differences between with and without irrigation access i.e. the actual change in impacts. The aim here is to separate out only the impacts that are clearly associated with irrigation development and not to include those impacts or changes that would have occurred even without the irrigation development. With and without approach is very useful when quantifying impacts of external intervention or policy. Two points are important here: (1) only incremental net impacts produced by irrigation access should be accrued to the irrigation factor; and (2) to properly identify the best actual opportunities foregone, i.e., the best alternative use of resources that would have actually taken place without irrigation development, considering various socio-political constraints.

In quantifying irrigation impacts, the viewpoint taken should be of the society as a whole and it is not restricted to the impacts only within the boundary of the irrigation command or the region. The scale dimension of irrigation makes assessment rather more complex. Some of the irrigation development projects are multipurpose—reservoir for hydropower, urban water use and irrigation. Impacts of each of these uses need to be quantified separately. Some of the impacts would be relatively easy to quantify that others, such as:

? Additional crop areas brought under cultivation (x mh)
? Change in cropping intensity (percent)
? Change in crop yields

? Change in net farm incomes
? Change in electricity production
? Change in fish production
? Change in tonnage transported
? Change in amount of waste disposal
? Change in number of recreational places developed
? Change in number of tourists
? Change in number of lives saved
? Change in person months of employment generated
? Change in area affected by salinity and water logging
? Change in loss of soil fertility
? Change in use of chemicals and fertilizers
? Change in number of people affected by water borne diseases
? Change in number of people displaced as a result of irrigation development;
? Other changes

These impacts may vary from one system/project to another, depending on the local conditions. For comprehensive impact assessment, these impacts need to be clearly defined and quantified. Data for some of these variables/indicators are available from published sources, from international agencies, national agencies/departments, donor reports, post-project evaluation reports and past research studies. Compared to data for economic indicators, data for social and environmental and ecosystem related impacts are rarely available and case study approach may need to be adopted.

8. Valuation of Impacts

Once the impacts of irrigation are quantified, the next step of impact assessment would be to value them, as far as possible, in monetary terms. Monetary valuations would allow us to directly compare costs and benefits of irrigation. Where monetary based measures are impractical or impossible, non-monetary indicators of economic value should be used. However, these indicators may be only partially useful for determining whether the economic benefits of irrigation exceed monetary costs. The following economic concepts and methods provide a useful theoretical basis for estimating the monetary value of quantified physical impacts.

Economic Value

The term value in any sense has meaning in relation to scarcity of resources. Economic value is one of the many possible ways to measure the value of resources. In economics, the generally accepted measure of economic value is based on what people want. It is a measure of the maximum amount of one good an individual is willing to forego to obtain more of something else, thereby, it reflects people's preferences and choices. Economic value is thus a measure of economic welfare, and it is formally expressed in a concept of willingness to pay (WTP). The economic value of goods or services for society as a

whole is the aggregation of individuals' value of goods and services across the number of consumers in a region.

For any resource, price are interpreted as expressions of willingness to pay (WTP) by consumers or producers. While this is obvious for marketed goods and services, where market price represents the willingness to pay at the margin, it is equally applicable to non-market goods and services where WTP provides a theoretical basis to determine prices referred to as shadow prices. WTP in the case of irrigation represents the value of incremental benefit of the impact, i.e., demand for the incremental service of irrigation. While benefit values can be measured from WTP, costs can be monetized using the concept of willingness to accept (WTA) and the concept of Opportunity Costs (OC) — which are the returns foregone where a scarce resource is used for one purpose instead of the next best alternative.

The net social benefits (NSB) or social surplus can then be determined by subtracting opportunity costs from from willingness to pay. NSB is the sum of consumer surplus and producer surplus. Consumer surplus is an area under the demand curve and above the price line, which represents the difference between the maximum users would be willing to pay over what they would actually pay. Whereas, producer surplus is the area above the supply curve and below the price line-which represents the difference between the minimum producers are willing to accept and what they would eventually receive-i.e., total revenues minus variable or opportunity costs.

For impact assessment, our interest is in a change in social benefits or surplus associated with increased water resource development, which results in increased amount of available water supplies. In perfectly competitive markets, market price of a good or service is a best approximation of the true value of that good or service. Under these conditions, price of a resource is equal to the marginal value product (MVP) of that resource and is also equal to the opportunity cost of that resource. However, perfectly competitive markets rarely exist in real world situations.

Water is a special resource. Markets for water either do not exist or are highly imperfect. Therefore, no competitive market prices exist for water. If prices exist (as in some developed countries), such prices fail to accurately reflect true social values of the resources based on the opportunity costs and they need to be adjusted. Where water prices do not exist, as in many developing countries, shadow prices need to be identified. The shadow prices can be derived indirectly from changes in impacts of irrigation where prices exist for such effects. In the case of irrigation development, it may be useful to classify irrigation-induced impacts based on the nature and type of market that exist.

1. Impacts or outcomes for which competitive markets exist. In such situations, price of a good or service represents the opportunity cost of the resource to the society, and it is equal to marginal value product, therefore, the market price can be used here to value the impacts of irrigation.
2. Impacts or outcomes for which the market exists but market price is distorted due to direct or indirect government interventions (subsidies and taxes, price controls and

other similar interventions). Under such situations, market prices are either under or over estimates of true social values of the impacts. The distorted prices can and should be adjusted to reflect the social values before using them in valuing irrigation impacts. The world market for any good or service is large and so more competitive than any domestic market. The world market price, therefore, is an appropriate reference price to adjust domestic prices, and to derive appropriate shadow prices, especially for tradable outputs. However, the use of prices and valuation will depend upon whether changes in outputs/impacts are small or large. If output changes are small, adjusted prices can be used to value the output. If output changes are so large to cause changes in prices, the benefit of changes in output should be valued on the basis of changes in consumer or producer surplus.

3. Impacts or outcomes for which markets do not exist. These are the impacts which are not exchanged in the market and they lack market prices e.g., reservoir providing recreational opportunities and more flood control, as these outcomes are not bought and sold in the market. However, these outcomes do change net benefits to the society and, therefore, should be valued using non-market valuation techniques and they should be included in the analysis.

Valuation Approaches

Economists over the past two decades have developed several methods for valuing benefits and costs of natural resources for which no market exist or markets are highly imperfect. Valuation methods/techniques are based on economic theory and applied economic principles. Some of these methods could potentially be adopted for valuing water. These methods may be classified into the following categories:

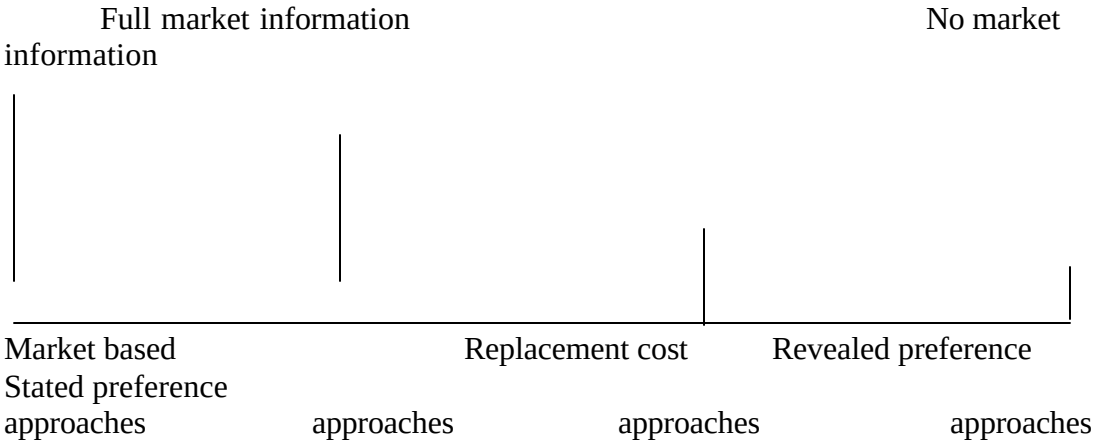
? Conventional market-based approaches—where goods are traded in the market and prices exist for inputs and /or outputs, prices (or adjusted prices) can be used as expressions of willingness to pay and the benefits and costs can be valued using market prices.

? Alternative/replacement cost approaches—these approaches can be applied to situations where market prices for some inputs or outputs do not exist or where direct estimations of demand and supply functions becomes difficult due to lack of data. Replacement cost approaches are based on the notion that maximum willingness to pay for any good or service is not greater than the cost of producing that good or service with alternative means of production or technology. The cost of producing that good or service is compared with cost of least-cost alternative means of producing that good and the difference represents the net economic benefit. The minimum replacement cost can be used as an estimate of the value of benefits of the good or service in question.

? Observed indirect or implicit or revealed preference approaches—where market prices do not exit, these approaches can be used to infer willingness to pay based on actual expenditure choices made by consumers—revealing their preferences. These approaches are based on actual consumer behavior where willingness to pay for a good or service is estimated indirectly.

? Stated preference approaches—these approaches are applicable to situations where peoples' preferences or willingness to pay cannot be inferred directly or indirectly from the actual behavior in the market. In these approaches, peoples' willingness is obtained through hypothetical markets where people are asked to express their willingness to pay or preferences for a good or service, through surveys.

All the above four approaches are based on sound theoretical economic concepts. However, in terms of their applications to the real world problems and the related complexities, some are more controversial than others. In general, the more the approach is based on actual market behavior and information, the more accepted it is. On a scale based on whether market information exists, the above approaches may be ranked as follows:



Each of the above approaches consists of a range of valuation techniques. The application of these techniques will depend on the specific nature of the problem. More than one technique may be applicable to a problem and the ultimate choice will depend on several factors including data availability, time and other resources. Some of these valuation techniques are explained below. For a more detailed discussion on specifics economic valuation methods and analytical tools, see Young 1996, Randall 1987, Pearce 1993 and Gibben 1986.

For the purpose of analysis, water uses may be classified into three broad categories:

A. Intermediate uses—where water is used in the production of other goods or services crop production, hydropower, etc.
B. Final consumption uses—where water is used as a final consumption good (commercial and domestic uses)
C. Water use for environmental purposes (in-stream flows, wetlands and landscape preservation).

Valuing Intermediate Uses of Water

Where water is used as an intermediate good, i.e., as an input in the production of other goods and/or services, economic theory of production could provide conceptual basis for valuing benefits and costs. Some such examples are:

Valuing Benefits of Water in Agricultural Production

Water is used as one of the several inputs in production of agricultural outputs. Where water is sold in well functioning markets, value of water or economic benefits of water can be obtained by analyzing water demand using market price information. But, as mentioned earlier, markets for surface water supplies are rare in the real world. In the absence of market prices, the value of water can be derived indirectly using the economic concept of production function. The change in productivity method (also known as the residual imputation method or change in net income method or intermediate good method) can be used to derive the imputed value or shadow price of water, provided the prices for other inputs and outputs exist.

Benefit or Value of Irrigation water = $NVO_w - NVO_{wo}$

and $NVO_w = GVO_w - C_w$

$NVO_{wo} = GVO_{wo} - C_{wo}$

Where NVO is the net value of output, GVO is the gross value of output, C is the total cost of production, subscript w and w_o represent with and without irrigation.

In applying this method, a number of assumptions will need to be made on the 'without' situation such as land use intensity, cropping intensity and types of crops grown in the absence of irrigation. The method is very sensitive to the quantities and prices of inputs used in the production process.

An important issue in applying this method is in relation to the contribution of other inputs such as fertilizers and improved seed varieties to increased productivity. These inputs are complementary to each other in irrigated agricultural production. The "with" irrigation situation enables farmers to apply increased amounts of fertilizers and use improved seed varieties, and it is their interaction which results in increased productivity compared to the "without" irrigation situation—thus the increased productivity in the "with" irrigation situation cannot be solely attributed to irrigation. However, the benefits from increase in irrigation-induced land use and cropping intensities and crop diversification can be solely attributed to irrigation—i.e. in the absence of irrigation, the expansions in these variables would not happen or the effect would only be negligible. In other words, the presence of irrigation alone would not increase the productivity to the level that will result from the combination of the three inputs. This is due to the differences in fertilizer and seed variety responses to crop yields in irrigated and dry land situations. Therefore, estimates of benefits from the above equations should be regarded

as upper bound on the estimates of irrigation benefits. However, these estimates can be adjusted by incorporating estimates of output elasticities with respect to the above three major inputs based on the estimated production functions or yield response functions:

$$Y = f(I, F, SV \ldots\ldots)$$

Where *I, F and SV* are quantities of irrigation, fertilizers and seed varieties (or areas sown with these inputs) respectively. The estimates of elasticities may be obtained by estimating production functions using pooled time series-cross-sectional data (to avoid multicollinearity problems) with econometric techniques or these could be obtained from secondary sources where data limitations do not permit such estimations.

Valuing Benefits Of Water In Hydropower Generation

Water is one of the most important inputs in hydropower generation. In multipurpose projects (as these are for most real world irrigation projects), benefits of water for electricity production must be estimated and included in the total benefits of irrigation development. An alternative or replacement cost approach offers very useful methods for imputing the benefits of water use for hydropower generation. As we know, electricity can be produced through alternative means—hydro, thermal (diesel, gas or coal), and wind etc.—the power generated from each of these sources can be assumed to be perfect substitutes for each other. Since the electricity price is generally distorted (regulated, subsidized), the first step is to estimate the value of electricity using the alternative cost approach. Assume that in the absence of water, that a diesel-based thermal power plant would be the cheapest alternative source of electricity production. The cost of producing a unit of electricity from this alternative source would be the replacement cost—which may be taken as a minimum estimate of the value of a unit of electricity generated. Since thermal-based power production also produces some pollution (negative externality), this added cost imposed on the society (pollution abatement cost) should be included in the calculations. The benefits of water in hydropower production can now be derived indirectly through the following equation.

$$\textit{Benefits of water} = Y_h * (C_{tp} + C_{tpp})_{tp} - TC_h$$

Where: Y_h is the annual amount of electricity produced from a hydro-plant
C_{tp} is the monitory cost of electricity produced from diesel-based thermal plants
C_{tpp} is the monetary cost of pollution (pollution abatement cost) per unit of electricity generated from diesel-based thermal plants. The TC_h is the total costs of production.

The estimates of pollution abatement costs can be obtained from secondary sources.

Valuing Benefits of Water in Industrial and Commercial Uses

In industrial and commercial sectors, water is used as an intermediate good (textile, beverage industries, etc.), but water is also used as a direct consumption good (drinking). In most countries, public utilities supply water to these sectors. While free market

conditions do not prevail (because of natural monopolies and state interventions in terms of subsidies etc), inferences on willingness to pay and demand estimates can still be made using observations on prices charged by utilities, and other related variables.

Three broad approaches can be adopted to estimate the value of water in industrial and commercial sectors:

1. Change in productivity method: Water can be taken as one of the inputs in the production of industrial outputs—to determine its value added to industrial and commercial activities and outputs. Value of water can then be estimated by subtracting the total cost of production (excluding cost of water) from the total value of industrial/commercial output, and attributing the residual as the value of water. However, there are number of limitations of this method: 1) unlike hydropower or agricultural sectors, water constitutes a small component in a bundle of industrial/commercial production inputs which makes residual value highly sensitive to prices and quantities of other production inputs; 2) this method does not account for the true value of the part of industrial water used for final consumption within industry.
2. Alternative/replacement cost method: Industrial/commercial uses of water can also be valued using the alternative cost approach. The cost of producing a unit of water from the cheapest alternative sources of production (e.g., groundwater pumping, direct surface water pumping, purification plants) is the replacement cost, and so is a minimum estimate of benefit of water in these sectors. If the relevant data are available, this method is relatively simple to apply.
3. Demand analysis using econometric approaches: Demand for water in industrial uses can be modeled as a function of the price of water, industrial output, alternative sources of water and technology of production. The specified functions can be estimated with cross-sectional, time series or pooled data using econometric techniques. The estimated price elasticities can then be used to estimate the area under the demand curve to obtain estimates of consumer surplus—and ultimately to determine the value of water. There is extensive literature on demand analysis for industrial and commercial water uses (see Hussain, Thrikawala and Barker 2002 for useful references on the subject). Estimates from secondary sources could also be used in situations where data limitations do not permit direct estimations.

Valuing Benefits of Water in Commercial Fish Production

Just like hydropower generation, commercial in-land fish production is not possible without water. As for other uses, water used for fish production is not priced (in most developing countries). A relatively simple varient of change in productivity method can be employed to estimate the benefits of water in this sector:

Benefits of water = $GVO_f - C_f$

$$GVO_f = Y_f * P_f$$

Where GVO_f is the annual gross value of output of fish, Y_f and P_f are annual amount of fish produced and average market price of fish, respectively, and C_f is the total cost of fish production (costs related to fish ponds, inputs such as fish feed and chemicals and cost related to fish harvesting—boats, nets, labor etc) excluding the cost of water. While data for annual fish production may be available form national agencies, cost components may need to be approximated from case studies or past research studies.

Valuing Transportation Benefits of Water

Where irrigation infrastructure is used for transporting goods or providing services, these benefits of water should be included in total benefit calculations. Again the alternative /replacement cost technique can be adopted to estimate such costs. The cost of transporting an X amount/number of goods/services through alternative cheapest means (e.g., surface transport) is the replacement cost, and it could be taken as the minimum estimate of benefit. Subtracting the costs associated with water transport from the above minimum estimate of benefit would provide an estimate of net benefit attributable to water.

Without going into too much detail about the specifics of the valuation techniques applicable to various impacts, we conclude that many of the impacts identified above could be valued using the above four broad approaches. In cases where impacts cannot be valuation does not make any sense we will use indicators describing the significance of the relevant impact.

Non-use Values

In the above sections, we dealt with the use values. There are also non-use-values that are also important in relation to water resources. Non-use values are also sometime referred to as sustainability values. Non-use values related to water include:

1. Option value: refers to the value that people place on maintaining the resource in order to keep the option of using it in the future, i.e., people are willing to pay today for the option to exercise future use of a resource (e.g., to avoid contamination of water to and to protect from irreversibility)
2. Existence value: refers to the value that people place on a resource knowing that it exists, regardless of any plans for current or future use by those people (i.e., existence value may be lost by the knowledge that water is being contaminated).
3. Bequest value: refers to the value people place on a resource from knowing that the resource is being preserved for future generations, i.e., present generation's preferences for bequest to future generations.

The total value of the resource will be:

Total value of the resources (TEV) = Use value (UV) + Non-use value (NUV).

Use value (UV) = Direct use value + Indirect use value;
and
Non- use value (NUV) = Options value + Bequest value + Existence value

Many resource economists argue that non-use values should be in estimating total value of a resource. However, measurements of non-use values are the most challenging part of the resource valuation exercise, as these values have no specific links to market behavior. Sometimes, it is suggested that inferences about non-use values could be made from what people are willing to pay to join organizations concerned with the use and sustainability of the natural resources (membership fees). However, methods for deriving such values from membership fees and patterns of voluntary contributions have yet to be developed. Occasionally, attempts have been made to estimate non-use values using the CV method—however these types of studies are mostly limited to developed country case studies (particularly the US), with only few examples of estimating these non-use values in the context of developing countries. Whether developed country valuation estimates could be applied to developing country situations through 'benefit transfer method' is very questionable. Also, non-use values are very sensitive to geographic assumptions—as people, in general, tend to place higher values on resources in closer proximity. Using values from local samples to obtain average aggregate values for a larger geographically extensive population is also very much questionable. Given all these conceptual issues and practical concerns, and the uncertain nature of these values, it is very debatable whether these values should be included in the cost-benefit analysis. It is generally suggested that where such values can be estimated they should be included in the analysis but where such values cannot be measured their possible significance should be discussed through qualitative descriptions. In the case of irrigation impact assessment, one can adjust the standard cost-benefit estimates by incorporating estimates obtained from past studies, and by developing estimates through case studies.

9. Estimation of Irrigation Costs

Irrigation involves several types of costs. These may broadly classified into three categories: economic costs, social costs and environment costs. These costs may be direct (cost associated with the direct provision of irrigation services, or infrastructure cots, such as financial costs and economic costs in terms of opportunity costs of resources use) where as others may be indirect (costs associated with the secondary effects of the project, like feedback effects and externalities). Some of these costs, especially those associated with negative externalities, may either be treated as dis-benefits of irrigation and analyzed under benefits/dis-benefits side or can be included on the cost side.

Major direct economic costs of irrigation include:

1. Capital costs
    - annual depreciation,
    - annual interest charges on capital

2. Operation and maintenance costs, including administration costs.
3. Rehabilitation costs

The capital costs include depreciation and interest charges associated with capital investment in irrigation infrastructure. These also include costs incurred on drainage works. Operation and maintenance costs include costs incurred in maintaining and managing the system. The specific components of these costs depend on the scale of analysis: national aggregate level, project level impact assessment or farm level impact assessment.

For the country level analysis, the entire irrigation infrastructure can be divided into two parts: (1) the system of dams, storage facilities and canals (main canals, branch canals and distributaries) that capture, store and distribute water to irrigated areas—primary and secondary levels; and (2) and local system of field channels carrying water to farms—tertiary level. While primary and secondary level infrastructure in most countries has historically been owned and managed by public authorities, the tertiary level infrastructure has been developed, owned and managed by farmers, except in cases where public authorities have implemented on-farm water management programs, e.g., pavement of water channels in Pakistan. Tertiary level irrigation infrastructure also involves costs including operation and maintenance costs, which are generally borne by farmers (mostly in kind). Whether costs of irrigation incurred by farmers at the tertiary level should be included in total costs of irrigation remains an issue.

The above cost categories may be classified as financial costs. In order to calculate true economic costs of irrigation development and management to society as a whole, other costs such as opportunity cost of capital and opportunity cost of irrigation water should also be considered. Various components of both financial and economic costs are shown in figure 7. Proper estimation of financial costs[5] of the project is important for determining the economic costs of the project, once the other indirect effects (costs) are estimated and valued in monetary terms.

Opportunity Cost of Capital used in Irrigation

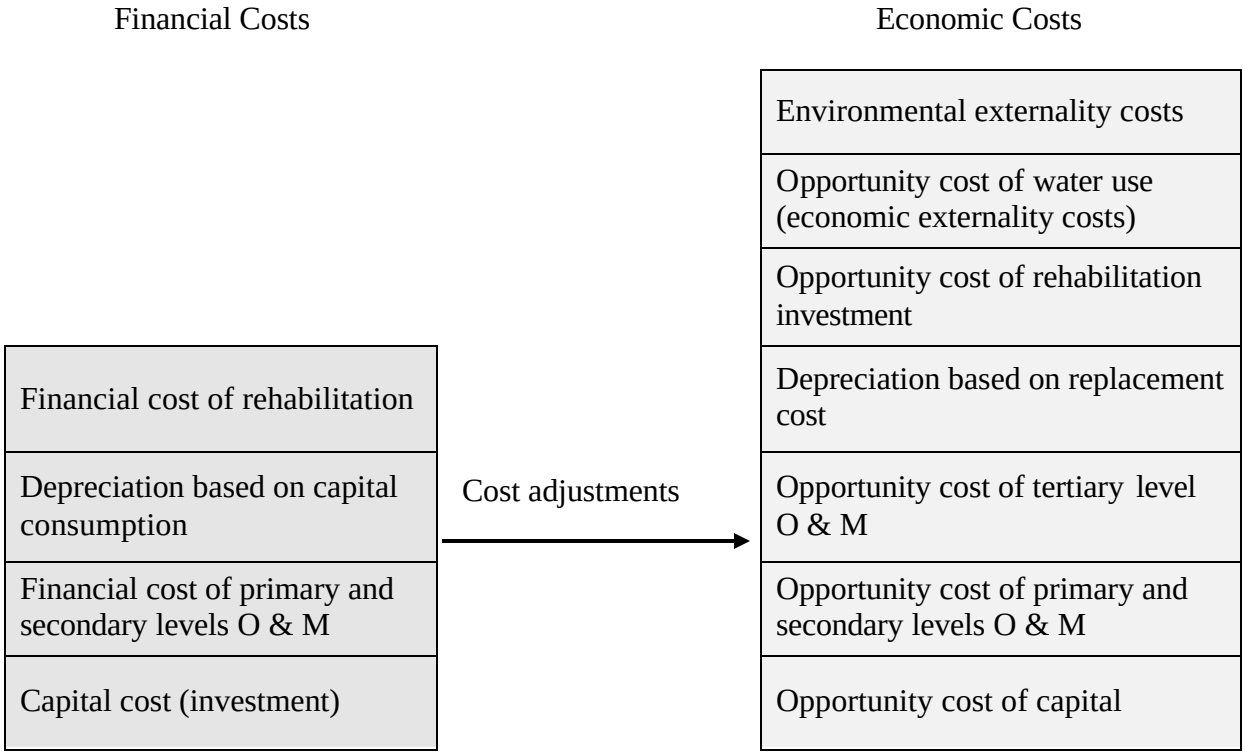
If irrigation investment is earning lower returns than what could be earned in other sectors of the economy, say in the development of infrastructure in other rural sectors such as rural roads, rural electricity, rural health and education, then this lost opportunity represents an economic cost to society. This would require a comparison of returns to investments in major sectors that compete for public funds. For simplicity, one can use the cost of making funds available from alternate sources (bank interest rate). For a large scale project funded by foreign agencies, the current interest rate of the multilateral agency interest rate is more appropriate as the opportunity costs of the capital invested in the project. Or, one can also use the social discounting factor for the capital used in the project, if it has been estimated earlier and is readily available to the analyst.

[5] In fact, the costs estimation process is a little simple at the project level, or at farm level than at he country level. The boundary of costs and benefits are clearly defined and the components of costs are mostly direct within the farm or project level analysis compared to the aggregate level analysis.

Opportunity cost of Irrigation Water

The marginal returns to water, or the value of water, vary across time, space and across water using sectors. Irrigation water has a very high value at certain times of the year, say it would be very high at certain critical crop growth stages as compared to other periods of crop growth. Value of irrigation water also depends upon the type of crops grown in an area, it would be high in a region growing fruits, and vegetables compared to an area growing fodder and other low value cereal crops. Similarly, the value of water would be high in sectors such as hydropower, industry, commercial, residential sector and certain environmental sectors (such as valuable wetlands) compared to many uses in agriculture. If water is allocated a low value and is utilized for agricultural uses at the expense of high value uses, the lost opportunity resulting from misallocation of water represents an economic cost to society. However, agriculture is the dominant user of water, the entire volume of water reallocated from agriculture cannot be used in other sectors or in locations where the value of water is very high, implying that the opportunity cost of water in agriculture would be zero after demands in other high value sectors are fully met. Thus, the opportunity cost of water would apply only to a certain proportion of the total volume of water used in agriculture, beyond which the opportunity cost would be zero. The opportunity cost applicable to that part of water would be equal to the estimated value of water used in other sectors.

Figure 7 : Various components of costs of irrigation development in a region.



10. Other Issues in Impact Assessment

Unit of Analysis

Irrigation development usually takes place in phases—project wise development. Each irrigation project has its own economic life, and associated benefits and costs. Projects implemented in the 1950s are different in many respects than those developed in the 1990s. Choosing the right unit of analysis is crucial for the impact assessment exercise. While choosing a project as a unit of analysis would be good for detailed assessments, undertaking an impact assessment analysis at the project level is not always very practical if the objective is to assess aggregate impacts. For aggregate level impact analysis, the most practical alternative is to carry out decade-wise impact analysis, since the impacts vary over time. Irrigation investments at the country level (lumping together irrigation investments made in all projects in a particular decade) can be assessed by making assumptions on the economic life of irrigation infrastructure developed and maintained during the particular decade. For projects developed during say the 1950s, costs and benefits can be estimated from the past data. For projects developed or rehabilitated in the 1990s, benefits and costs will need to be forecast based on a set of assumptions on the future impacts of these projects.

Discounting

Another related issue is that costs and benefits generated out of the irrigation project are spread over time, rather than occurring at the one same point of time. Time has an influence on the value of costs and benefits. In order to make direct comparisons, the costs and benefits must be expressed in a common measure. The general approach is to apply an adjustment factor to cost-benefit values that reflect their present value through the procedure called discounting. The adjustment factor or the rate at which costs or benefits are discounted is known as the discount rate (interest rate). While comparisons of costs and benefits using discounting procedures are widely accepted, use of a specific discount rate is highly contentious. In general, the choice of discount rate depends upon three economic principles: 1) the opportunity cost of capital: this is based on foregone benefits when capital is invested in one project rather than another, which is equal to the opportunity cost of capital. In a competitive market, this is closely related to the nominal interest rates and rate of returns on private investments; 2) social rate of time preference—these are based on the notion that individual decisions differ from social decisions, individuals or private decision-makers are relatively short-lived and tend to over-consume in the present rather than save for the future. Societies exist for longer periods, therefore there is a need to assign a lower discounting rate to a social investment

like irrigation development. The low discount rate associated with social rate of time preference reflects precisely this view that societies discount the future less than individuals; and 3) cost of borrowing money, which is an alternative approach to set the discount rate, especially when funds are borrowed from abroad. One can even take the lending rate of the foreign agency, including the interest rate adopted by the multilateral agencies like the Asian Development Bank (ADB) and the World Bank (IBRD, IFC and IMF).

It is generally argued that the use of a higher discount rate may discriminate against future generations as projects with benefits occurring in the long run would be less likely to be undertaken. The counter argument is that the lower discount rate would lead to increased investments—because with lower discount rates most projects would appear to be economically viable undertakings, which in turn may worsen environmental degradation and negative impacts on the sustainability of resources availability (an extensive discussion on these issues can be found in Hasley and Splash 1993). There is no simple answer for selection of a correct discount rate that could be used in cost-benefit analysis. In practice, the discount rate which is generally used by the planning authorities of the respective country is used in cost-benefit analysis of a developmental project, or else project analysts should use a specific discount rate (say 10 percent) and undertake sensitivity analysis with alternative rates. Sensitivity analysis is also needed to incorporate and analyze risk and uncertainty about future benefits and costs of irrigation, which can be performed using optimistic and pessimistic values of variables.

Measures of Comparison

Once all the benefits and costs have been identified, quantified and valued and an appropriate discount rate has been chosen, the next step is to develop a common measure or index, which allows direct comparisons of costs and benefits. Several measures have been proposed in past studies. The most commonly used measures include: net present value (NPV), economic rate of return (ERR) and benefits cost ratio (BC). NPV is equal to the present value of benefits minus the present value of costs. All values (estimates of past, present and future costs and benefits) including estimates of discount rate should be expressed in real terms instead of nominal terms, i.e., adjusted for inflation.

$$NPV = ?_{t=0}^{n} (B_t - C_t)/(1+i)^t$$

Where: B_t = benefits in year t; C_t = costs in year t; n = number of years; and i = discount rate

The NPV of benefits and costs will be compared to see if benefits exceed costs. The NPV measure will allow us to remove the effects of different time values associated benefits or costs gained or forgone at different times.

ERR, another useful measure, is the rate of return on investment funds per period during the life of a project or in other words ERR is the rate that makes NPV equal to zero.

$$NPV = ?^{n}_{t=0} (B_t - C_t)/(1+ERR)^t = 0$$

Where all symbols are as defined above. An ERR indicates per period yield of resources used in the project. An ERR of 10 percent indicates that US$100 invested in the project would generate returns of $10 per year throughout the project's life. In sum, NPV and ERR may be used to compare costs and benefits of irrigation and to determine returns on irrigation investments.

Appendix

Other Non-market Valuation Techniques

In the presence of an observed market for a resource, market price is a most relevant basis for the valuation of the resource. In the absence of any observed market and transaction of a resource, the resource value has to be estimated based on indirect methods, that is, either by estimating derived demand curve, or through hypothetical markets, or following opportunity cost approach, hedonic pricing approach, or household production function approach. Brief descriptions of some of these approaches and methods are given below.

1. Contingent Valuation Methods (CVM)[6]

In the absence of markets, CVM can be used to assess the value and users' willingness to pay for the goods and services related to irrigation, such as farmers willingness to pay for irrigation services, flood protection, drainage services, etc. CVM measures people's attitudes and preferences towards a good by constructing a hypothetical market scenario. The information generated through CVM is an ex-ante measurement of an individuals' valuation of a particular good or service.

CVM estimates the economic benefit (cost) of non-market goods through the construction of a hypothetical market. The structure of the hypothetical market or institution is framed in such a way that it would reveal the participants true demand (or supply) for such goods and services (Portney 1994). The individual affected by the irrigation project (public good) can be interviewed and asked how much money they would be willing to pay (WTP) for successive additional levels of irrigation services, or their willingness to accept (WTA) reduction of successive irrigation services. Later, the individuals' values can be aggregated, to find a market-demand schedule for such goods, which is otherwise not possible to get from the usual market data. Following are some of the major strengths of CVM over other methods of valuing non-markets goods and services:

? CVM is the only currently available technique capable of providing monetary estimates of the magnitudes of many environmental damages (losses), or valuation of impacts on ecosystems and biodiversity.

[6] CVM is used for estimating non-use values of environmental goods and services, particularly in public funded projects, including water development projects. Detailed discussions on CVM methodologies and estimation procedures can be found in Mitchell and Carson 1989 and Freeman 1993.

? CVM is a flexible tool, and the market structures and institutions of the trade off in CVM and substance of contingent questionnaires can be constructed to reflect the need of a specific policy tool. This technique allows for estimation of the quantity and quality dimensions, temporal and spatial dimension of the value of a resource, including property right entitlements.
? Data from CVM can be generated in a manner consistent with the theory of individual choices and welfare measurement.
? CVM captures the ex-ante planned expenditures that could be reliable measures of an individual choice and welfare change by a project intervention. Hence, CVM can elicit both use and non-use values of resources (environment services), thereby, it can determine a complex ex-ante measurement of the value of non-market goods and services.
? Non-use values are not revealed by the indirect valuation methods (such as travel cost method, hedonic pricing method), since indirect methods capture only the current consumption. Whereas, CVM effectively captures non-use values of environmental resources, constructing a market for future uses such that it precisely reveals the individual's value and preference over time and space. The most commonly used non-use values such as, option value, existence value and bequest value can be effectively determined by the flexible ex-ante CVM tool.

While CVM has been extensively used for assessing environmental damages in the recent past, it has several limitations. Some of the major shortcomings of CVM are:

? Hypothetical bias: Information obtained from CVM is based on hypothetical questions in the contingent markets that are likely to generate some degree of bias and potentially invalid value estimation. This arises when the survey is not designed realistically incorporating, the locale specific characteristics.
? Information bias: Due to the nature of the survey, if respondents are not given enough information about the nature of the simulated market and available substitutes, this could reveal biased value estimates (information bias). The value chosen by an individual depends on the policy design of institutions and payment mechanism, therefore the difference in the individual's ex-ante value may not be an unexpected phenomenon.
? Strategic bias: This arises because of the respondents' self-interest to influence the policy outcomes of the study. Respondents may favor a new project by overstating the hypothetical value (WTP) far from the reality. However, this problem can be minimized by taking adequate care while designing the questionnaires, and including cross questions in the survey, etc.
? Payment vehicle bias: The form of payment proposed in the hypothetical market may influence the CVM results. The responses may differ with the value of the starting bid, i.e., instrument bias. This, however, can be minimized by properly selecting the starting points for bidding.

2. Hedonic pricing[7]

The hedonic pricing technique is an example of revealed preference approaches, where the main assumption is that the price of some marketed goods and services in question is a function of its different characteristics, and an implicit price exists for each of the characteristics. Here, resource is defined in terms of services it yields or an attribute it embodies, and the attribute is linked with other goods and services that are marketed and priced. Consumers recognize various attributes of the environmental goods, but these attributes cannot be separated when purchasing the goods in the market. For example, water quality related issues, health and safety risk of wastewater uses, land quality based on soil fertility, land prices based on differential access to irrigation facility, land fertility, etc.

The hedonic pricing technique is based on a concept that wherever the choices are available, information on demand for public goods (environmental quality change induced by irrigation) is embedded in the prices and consumption levels for private goods. If the good in question contains different combinations of characteristics, then one can estimate an implicit price of a characteristic as a function of the quantities of its various characteristics. This relationship is called the hedonic price function, usually estimated from a regression model. The partial derivate of the hedonic price function with respect to any of the characteristics of the product gives its marginal implicit price, i.e., the additional expenditure required to purchase a unit of the product with a marginally larger quantity of the particular characteristics. In the second step, an inverse demand curve can be estimated with regression analysis. This allows to stimulate the implicit price that people are willing to pay for a certain level of environmental improvement, obtained from the first stage regression related to average characteristics of the goods and services in questions.

The main limitation of the hedonic pricing approach is that it can only measure the use-value of goods and services in question for which people are willing to pay, and they do so through the related product markets. It does not measure the total economic value of public goods and services in question but only measures a subset of use value. If the consumers are not fully informed about the quantities of the attributes being valued, hedonic pricing estimates may not be so reliable. Besides, when there is a large change in environmental quality, there could be a problem with the weak separability assumption inherently built upon in the hedonic pricing model. Similarly, small sample size and uncertainty about the choice of relevant variables and choice of functional form of regression models may influence the implicit prices and value of resources estimated from the hedonic pricing technique. In practice, this technique is commonly used in valuing characteristics of housing, based on land quality, landscape and locational characteristics.

[7] A detailed discussion on the hedonic pricing method can be found in Freeman 1993; Young, 1996.

References

Bakker, M.; R., Barker; R. Meinzen-Dick; F. Karradse. 1999. *Multiple uses of water in irrigated areas: A case study from Sri Lanka.* SWIM Paper. Colombo, Sri Lanka: International Water Management Institute.

Dhavan, B. D. 1986. Irrigation in India's agricultural development: Productivity, stability equity. New Delhi, India: Sage Publications Inc.

Freeman III; A Myrick. 1993. *The measurement of environment and resources values: Theory and methods*. Washington DC, USA: Resources for the future.

Gibben, D. C.; 1986. *The economic value of water*. Washington DC, USA: Resources for the future.

Gittinger, J. P. 1982. *Economic analysis of agricultural projects.* EDI series on Economic Development. Washington, DC : The World Bank..

GWP (Global Water Partnership). 2000. *Integrated water resources management*. TAC background papers No. 4. GWP. Stockholm, Sweden.

Hanley, N.; and C.L. Splash. 1995. *Cost-benefit analysis and the environment*. Brookfield, VT: Elgar Publishing.

Hussain, I. and S. Thrikawala and R. Barker. An economic analysis: Residential, commercial and industrial uses of water in Sri Lanka. Water International (fothcoming)

Mitchell, R. C. and R. T. Carson. 1989. *Using surveys to value public goods: The contingent valuation method*. Washington DC, USA: Resources for the Future.

Pearce, D. 1993. *Economic values and the natural world*. Cambridges, Massachusetts, USA: MIT press.

Perman and McGilvray. 1996. *Natural resource and environmental economics*. London, UK: Longman.

Portney, P.R. 1994. The contingent valuation debate: Why economists should care. *Journal of Economic Perspectives (JPE)*, 8(4): 3-17, fall 1994.

Randall, A. 1987. Resource economics: An economic approach to natural resource and environmental policy. New York, USA: John Wiley and Son.

Skilomanov, 1997.

WCD (World Commissions on Dams). 2000. Dams and development: A new framework for decision making. UK: Earthscan Publications.

Young, R. 1996. Measuring economic benefits for valuing water investments and policies. World Bank Technical paper No. 338. Washington D.C. USA: The World Bank.