Dialogue

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Working Paper 3

Comprehensive Global Assessment of Costs, Benefits and Future Directions of Irrigated Agriculture

A Proposed Methodology to Carry out a Definitive and Authoritative Analysis of Performance, Impacts and Costs of Irrigated Agriculture

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/irrigated farming/water management/cost benefit analysis/performance/policy/environment/food production/ rural development/planning/

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The Setting

During the last 50 years, there has been an unprecedented expansion in the area of irrigated. Massive investments have been made in irrigation to achieve food security, to stimulate rural development and to combat poverty. Besides financial costs, other costs have been incurred to meet these aims including increased stress on water resources and environmental degradation. How far have the goals of irrigated agriculture expansion been achieved, and at what cost? How much more irrigation will we need to meet the future needs of a growing world population?

The answer to the last question—how much irrigation do we really need—is arguably the most important information we need regarding future water resources development and management, yet one where there remains tremendous uncertainty. To keep pace with growing population and food demands, estimates have been made that irrigation will have to expand by some 20% to 30% by the year 2025 (IWMI, Shiklomanov). From another perspective supported by some environmentalists and a few other agricultural stakeholders, a slowdown in dam building combined with falling water tables will limit irrigation expansion to between zero and 10%. Neither view is very attractive, as a 30% increase will stress water resources and ecosystems, while a no-growth scenario could lead to food shortages and poverty aggravation. Alternative solutions to these trade-offs between food and economic security and ecosystem health must be found.

The Debate

The answer to the question on how much irrigation is needed is largely dependent on perceptions about answers to the first question—what have been the real benefits and costs of irrigation? Many people feel that the costs of irrigation in terms of diminished environmental services, displaced people, and poor returns due to poor agricultural performance have far outweighed benefits. Many feel that future food needs can be met by better use of rainwater, and smaller, more environmentally friendly agriculture. Others feel that irrigation has played a significant role in poverty relief and food production, and that the only way to meet future demands is to do more irrigation, and do it better than we do now. They feel that irrigation is an important tool to solve food and employment problems in large parts of Africa and Asia.

As always, the answer probably lies somewhere in the middle. There are situations where irrigation can be greatly improved, situations where there should not have been irrigation and other situations where much more is needed.

Polarization and Values

The problem is that the debate is now highly polarized. The present debate relies only on scattered pieces of evidence, rather than on a comprehensive picture of the benefits and costs of irrigation. It is easy for both sides to pick stories that demonstrate their case, yet neither side agrees on the basic information for the debate.

This polarization results in a gridlock in the necessary constructive dialogue and, ultimately, in a lack of action. Investments in irrigation, whether in new infrastructure or in improvements have slowed down. We are not spending the time, funding and energy to identify alternatives. Meanwhile, poor people are waiting and we continue to mine environmental reserves for food.

The Global Water Partnership Framework for Action to achieve the Vision in the 21st Century captures the paradox:

"On the one hand, the fundamental fear of food shortages encourages ever greater use of water resources for agriculture. On the other, there is a need to divert water from irrigated food production to other users and to protect the resource and the ecosystem. Many believe this conflict is one of the most critical problems to be tackled in the early 21st century."

A Conflict of Values

Much of the polarization is cast in strongly value-laden language by both sides in the debate:

The Sierra Club mandate states:

> "Our work reflects the core values of people everywhere. That we all have a right to a safe and healthy environment, clean air, clean water, open space, wild lands and a healthy and diverse ecosystem. We join the American people, and citizens of every nation, in the effort to protect our precious environment. For our families, for our future."

Water and Nature Report of the World Water Vision contained this finding:

> "Ecosystems and the life they contain have a right to the water they need to survive, to preserve their intrinsic values and enable them to continue to provide goods and services to humankind."

The International Commission on Irrigation and Drainage (ICID) states:

> "Irrigation increases productivity and value of land, which brings prosperity, which in turn facilitates installation of infrastructure.…Survival, development, growth of rural economy and well being thus become synonymous with water, food and agriculture…. The water for food sector needs to enlarge withdrawals within the next 25 years by 15–20%. This calls for a massive increase in investments from government and nongovernment sectors."

Robert Solow, Nobel Laureate, Economics (1989) reminds us that:

> "If 'we'—the people making economic decisions now—have any sort of obligation to steer economic growth in a sustainable direction, it must be because we think it would be unfair or unsound to use limited resources for current benefit in ways that will impoverish future generations. A decision to seek sustainability is thus a decision to avoid a certain kind of inequality. It is not a good thing that 'we' should be well off, or get better off, if that entails that our (distant) descendants will be much poorer than we are. If 'human development' is the underlying goal of economic growth, human development should he equitably shared between the present and future…

> “Why is it so important that we protect the distant future from a fate that arouses so little concern and action when experienced by contemporaries? If we agree that human development is the goal and economic growth is the means, current productive capacity is just as eligible a means.”

As the debate on irrigation and its future continues we must separate facts from values and focus the debate on policies and societal preference, and not on conjecture about benefits and costs to humans and ecosystems.

Policy Making under Multiple Objectives

Figure 1 presents the debate over irrigation and ecosystem protection/conservation in a visual and economic framework and provides insights into the reasons for the policy conflict and possible hope for future actions.

Figure 1. Framework for analysis of water for ecosystems and water for agricultural production.

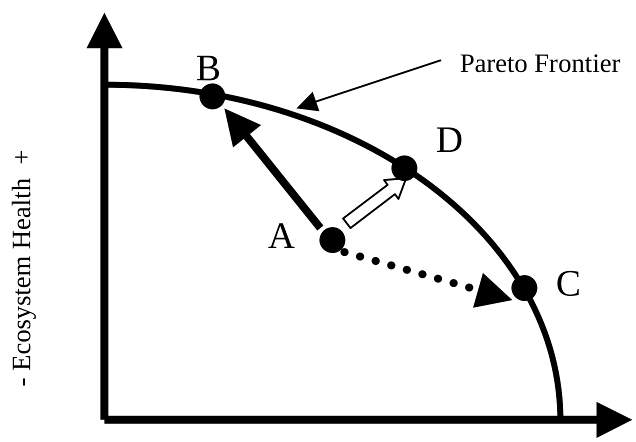


Figure 1 shows the decision space of alternative irrigation polices and the level at which they satisfy the dual objectives of Ecosystem Protection and Agricultural Production. The curve labeled the “pareto frontier” is the collection of policies where increasing the value of one objective can only be achieved by decreasing the value of the other objective. This is often referred to as a “trade-off” curve. Feasible policies can be any point on the curve or in the area to the left of the curve. However, those points or policies to the left of the curve are not “pareto” efficient in that one objective could be increased without adversely affecting the other objective.

Empirical data suggest that the irrigated agricultural system is currently not operating at optimal efficiency. We assume that the current condition is at point A. Those who value ecosystem protection desire the development policy to be a point as far along the vertical axis as possible while those concerned with food production desire it to be as far along the horizontal axis as possible. Thus the policy question then is how do we move from point A in the future. Economics tells us that we should be at a point on the curve, but where on the curve is a matter of societal preferences and the perceived relative values of ecosystems and agricultural production.

Facts: Defining the Trade-off Curve: The first item needed in the policy-making process is to determine the trade-off curve. This is a “technical” activity but still faces issues of values as analysts decide on what and how to measure the achievement of each objective. There is much to be learned before we can plot this curve. However, with sufficient resources and time it is achievable

*Values: The Path to the Future:*Interpreting the preferences of the parties quoted above shows that the Sierra Club might prefer a future at point B, while the ICID might prefer it at point C. These points, while meeting the goal of being on the pareto frontier, both lead to decreases in satisfaction for the other party.

However, there is a point D, which is a compromise point for both parties. It is on the pareto frontier and increases the level of satisfaction of *both* parties over the current state at A, but not as much as their alternatives B and C.

The current climate and debates lead one to feel that we are headed to either point B or point C. However, there is a path for the *Future Directions of Irrigated Agriculture* that leads to point D.

Post-facto evidence of the fact that water management and irrigation need not necessarily incur unacceptable ecological costs is that some water-management schemes have resulted in regionally and internationally important ecological benefits. For example, the development of rice-field irrigation in southern Louisiana and Texas has resulted in these areas becoming the most important wintering sites for shorebirds and waterfowl on the east and Gulf coasts of North America (Remsen et al. 1991). Also, irrigation of the Central Valley in California replaced native semiarid habitats with irrigated fields, to the detriment of the biota that previously occupied these areas. Nevertheless, it also created an internationally important wintering and migration site for waterfowl and shorebirds, while also resulting in highly productive and valuable agricultural land. Work in Tanzania by Lankford and Franks (2000) has also shown that with an acknowledgement of the spatial and temporal dynamics of wetland ecosystems and proper planning, wetland ecosystems and rice production can coexist.

With the possible impacts on ecosystems and potential for increases in hunger, there is an urgent need to add some structure to the debate on irrigation and engage in a scientifically informed and civil dialogue among all parties to avoid injury to either humans or the ecosystem and develop *win-win policies.*

Search for a Common Understanding

The purpose of this document is to propose the undertaking of a *Comprehensive Global Assessment of Costs, Benefits and Future Directions of Irrigated Agriculture* to provide information to help move the debate forward, and to chart a path for the future. The goal is to assist in informed and effective policy making. This is a challenge that existing scholarship and policy experience have not prepared society to meet. Knowledge relevant to the management of global environmental change is growing rapidly. But it remains incomplete, selective, and contested across nations and cultures. Relevant policy making has likewise advanced substantially in recent years. But it remains fragmented, diffuse and tentative (Clark 1999).

This project will provide a comprehensive assessment of the benefits and costs of irrigation over the last 50 years. The exercise will be comprehensive in that it will cover key benefits and costs including those related to food, livelihoods and the environment. It will be comprehensive in that it will be global in scope, and cover a relatively large time period.

The specific objectives are to:

- strengthen the knowledge base on water for food and environmental security

- develop conceptual, research and assessment tools to address water-food security and environmental trade-offs in an integrated framework

- provide feedback into a global dialogue that will strive to gain consensus among key stakeholders from the irrigation, environment and rural development communities on the role irrigated agriculture plays and should play in the future

To meet these objectives, this project will support a definitive and authoritative analysis of performance, ecological impacts, and costs and benefits of irrigated agriculture within the wider context of integrated water resources management.

The Assessment Framework

How does one proceed to undertake an assessment of this magnitude and importance? The maturing discipline of *Environmental Impact Assessment* (EIA), a process of predicting and evaluating the effects of an action or series of actions on the environment, then using the conclusions as a tool in planning and decision making, has evolved over the past 30 years. It is a process that is promoted and supported by the major contributors to the debate described above:

> *Principle 17 of the 1992 Earth Summit Rio Declaration encourages the undertaking of* ***Environmental Impact Assessment*** *for proposed activities that are likely to have a significant adverse impact on the environment and are subject to a decision of a competent national authority. Chapter 8 of Agenda 21 refers to "comprehensive analytical procedures for prior and simultaneous assessment of the impacts of decisions, including impacts within and among the economic, social and environmental spheres," which procedures "should extend beyond the project level to policies and programmes"* (Ramsar 1996).

The class of EIA that extends to "policies and programmes" is usually known as Strategic Environmental Assessment (SEA), or Programmatic EIA. This is concerned with the assessment not just of single projects, but of the cumulative effects of several projects, and the frameworks of programs, plans and policies within which they are promoted (see, e.g., Therivel et al. 1992). Policy appraisal for the environment is a similar type of idea, and "sustainability analysis" is also linked.

The core question of this exercise is "What is the environmental impact of irrigated agriculture?" This exercise could more precisely be classified as a Programmatic EIA or SEA. Therefore, it seems only natural that this proposed assessment follow the guidelines of EIA.

There are many forms and guidelines for SEAs. Most contain the following components:

1. **Retrospection:** Reviewing past environmental trends and the impacts caused by human actions.
2. **Auditing:** Documenting the existing state of the environment and the likely effects of proposed actions (and possible alternative actions).

3. **Analysis:** Predicting the state of the future environment with and without the proposed actions (the difference between the two is the impact of the action).
4. **Mitigation**: Considering methods for avoiding, eliminating or reducing any negative impacts, and possible compensation for them.
5. **Dialogue**: Opening a dialogue among analysts, stakeholders and decision makers by instituting a feedback process on measurement, methodology, scope of the impact analysis and presentation of results.
6. **Monitoring and Adaptive Management**: After a decision is made about whether/how the actions should proceed, monitoring the impacts which do occur, and acting on the results of such monitoring to further minimize ecological impacts.

The ultimate objective of the exercise proposed in this document is to provide the framework and information needed to begin step 5 of the SEA: "**Dialogue**." A methodology to carry out a definitive and authoritative analysis of performance, impacts and costs of irrigated agriculture within a SEA framework will be described below.

Methodology

One of the major barriers to effective implementation of environmental impact assessments is the lack of agreement and understanding between stakeholders, decision makers and analysts regarding the types of impacts to be assessed, the analytical techniques to be employed, and the data and metrics that will be used. This often results in excellent assessments not being implemented, and an even greater "gap" developing between opposing views. An example of such failure is the response of the International Rivers Network to the World Water Vision report, which is entitled "Old Water in a New Bottle." An example of a successful EIA is the Glen Canyon Environmental Impact Statement that has led to the changed operation of the Glen Canyon Dam and releases of artificial floods for ecosystem maintenance in the Grand Canyon. The flood releases and the operational changes both come at the cost of lost hydropower revenues. The consensus that developed for the changes was the result of a very long, expensive and difficult exercise. The key to the success of this process was the acceptance by all parties involved of the tools and data that were used to analyze the impacts, and the metrics that were used to measure the impacts (Gold 1996).

For this SEA to achieve its goal of constructive, productive dialogue among those in the water, environmental and agricultural communities who are concerned about irrigated agriculture, the assessment must use data, metrics and models that all parties agree on, and allow for debate over values and priorities, rather than for debate over technical issues.

To achieve this goal, the assessment must develop an "adaptive analysis framework" that allows for early input from all concerned parties about the design and implementation of the assessment, rather than at the process conclusion. Additionally, the adaptive analysis framework should allow for a plurality of analytical methodologies that can provide insights into different aspects of the problem.

The two key elements of the SEA that must have consensus are 1) measuring impacts and 2) modeling future impacts. The key issues related to both of these will be discussed below.

Measuring Impacts

The key element of this SEA is assessing the impact of irrigated agriculture on the environment.

> *According to the American Heritage Dictionary, 2000, assessing is determining the value, significance or extent of something. In this case the impacts, cost and benefit, and performance of irrigation.*

This requires measuring impacts to environmental, social, economic and institutional systems. It also requires using some metric that will allow the ranking of alternative actions regarding their impacts on the above systems, while being explicit about the directions and magnitudes of trade-offs that may be incurred.

Measuring Benefits of Irrigated Agriculture

Market impacts. Benefits of irrigated agriculture are generally measured as the additional economic value of the irrigated crops over rain-fed crops. Gittintger (1982) in his classic *Economic Analysis of Agricultural Projects* provides an excellent guideline for such analyses.

Nonmarket impacts. Irrigated agriculture provides a number of nonmarket benefits such as food security, nutritional health and rural employment. These nonmarket benefits and their potential changes must be measured by some metric.

Measuring Costs and Benefits to Ecosystem

Water management schemes that have resulted in adverse ecological effects bear clear testimony to the need to include ecosystem considerations in the planning process. The real question is not whether we should do this, but how? A planning approach that seeks to minimize ecosystem injury at the same time as optimizing the yield and sustainability of irrigated agriculture must be developed and applied. It is important that this approach should also be able to identify and quantify the trade-offs that might arise between development and ecosystem health and services. Such an approach should be able to rank alternatives in terms of their likely degree of ecological impact, and integrate the needs of the local/regional communities and economies with those of the exploited and affected ecosystems, so that both retain sustainability.

If such an approach is to be developed and applied, it is important that it be based on firm ecological principles and on empirical evidence. Irrigation schemes around the world provide valuable opportunities to obtain the latter.

Market impacts (ecosystem services). Human societies derive many essential goods from natural ecosystems, including seafood, game animals, fodder, fuelwood, timber and pharmaceutical products. These goods represent important and familiar parts of the economy. What has been less appreciated until recently is that natural ecosystems also perform fundamental life-support services without which human civilizations would cease to thrive.

The process of waste disposal, for example, involves the life cycles of bacteria as well as the planet-wide cycles of major chemical elements such as carbon and nitrogen. Such processes are worth many trillions of dollars annually. Yet because most of these benefits are not traded in economic markets, they carry no price tags that could alert society to changes in their supply or deterioration of underlying ecological systems that generate them. Because threats to these systems are increasing, there is a critical need to identify and monitor ecosystem services both locally and globally, and to incorporate their value into decision-making processes (Daily 2000). Ken, do you mean her 1997 book?

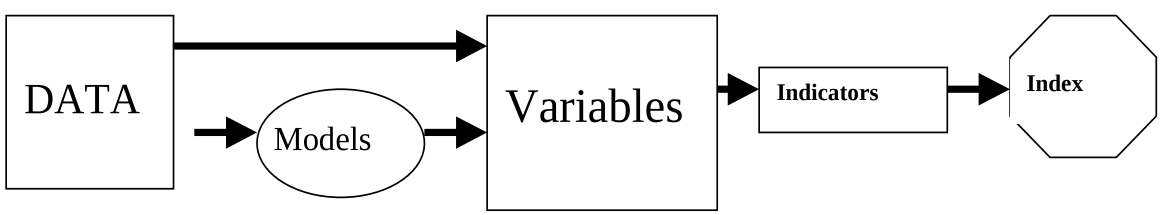
A recent development has been the attempt to put "economic values" on the services that ecosystems perform for humankind. Constanza et al. (1997) have pioneered this effort, with refinements and local- scale applications beginning to enter the EIA arena. The issue of "who" sets the values is still a major question facing the approach.

Nonmarket impacts. The classic way of assessing or measuring impacts, both good and bad, on ecosystems is via "indicators." Indicators are useful tools in gauging the state of national economies: the unemployment rate, the inflation rate, gross domestic product and others. Unfortunately, the identification of ecological indicators is still in its early stages of development and there are no generally accepted measures. Decision makers are faced with conflicting information about ecosystem conditions, conflicting views on what is important to consider in reaching a decision, and few sources of information that are widely perceived as unbiased. There have been some recent attempts to develop ecosystems indicators, most notably at the international level. These have included the Pilot Environmental Sustainability Index (Esty 2000) and for the USA the work of The H. John Heinz III Center for Science, Economics and the Environment Report on the State of the Nation's Ecosystems (O'Malley 2000). The selection of appropriate measures and indicies (to be discussed below) should be one of the first orders of business of the assessment.

Indicators

The objective would be to develop a series of indicators and, possibly, a single index analogous to the Human Development Index (HDI) or Environmental Sustainability Index, to measure human and ecological dimensions of irrigated agriculture. Figure 2 shows a conceptual outline of the process of index derivation.

Figure 2. The process of indices development.



The important indicators for an Irrigation Impact Index (III) should include:

(1) ecosystem
(2) hydrologic
(3) socioeconomic institutions
(4) water infrastructure
(5) water quality

Each of these components may include several factors that can, in turn, comprise a number of variables. Table 1 shows a conceptual outline of the parameters that could be used in deriving the III.

Table 1. A conceptual outline of the factors and variables and their interrelationships that could be used in deriving the III.

Indicator	Factors	Variables
Ecosystems	Aquatic/terrestrial environmental quality	Number of native fish species
		Survival of juveniles
		Size of river basin
		…
	Biodiversity	Keystone species
		Genetic variability
		Landscape diversity
		CO_2 atmospheric concentration
	…	…
Hydrologic	…	…
Socioeconomic	…	…
Water infrastructure	…	…
Water quality	Surface water quality	Biological oxygen demand (BOD)
		Suspended load
		Total coliform
		…
	Groundwater quality	Total dissolved solids (TDS)
		Chloride concentration
		Volatile organic carbon (VOC)
		…
	…	…

Scale of Analysis

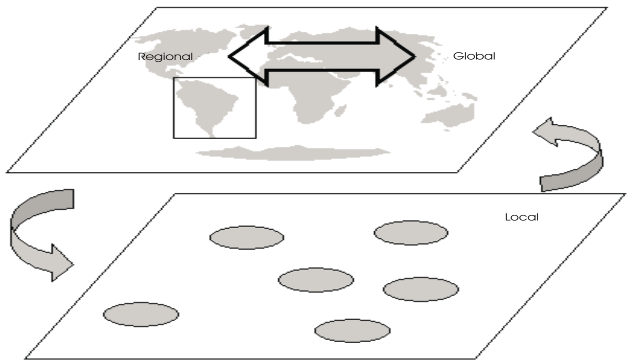
The assessment will be carried out at three scales:
- a global scale
- a regional scale to identify key issues by regions, and to feed into the global-scale analysis
- case studies at both national and basin levels to provide information on issues faced “on-the-ground”

Multi-Scale Integration of Information

The analysis should not follow the three research paradigms that have been traditionally used: scale-up, scale-down, and scale-up with embedded scale-down components. None of these approaches by themselves can provide the most reliable ecological assessments. However, Root and Schneider (1995) described a potentially more effective paradigm which they labeled strategic cyclical scaling (SCS). SCS involves continuous cycling between large- and small-scale studies, thereby offering improved understanding of the behavior of complex environmental systems at widely different spatial scales, allowing more reliable forecast capabilities for analyzing the ecological consequences of global changes.

SCS, however, is not only intended as a two-step process but also as a continuous cycling process between large- and small-scale studies, with each successive investigation building on previous insights from all scales. This approach is designed to enhance the credibility of the overall assessment process. SCS as it could be applied to SEA is outlined in figure 3.

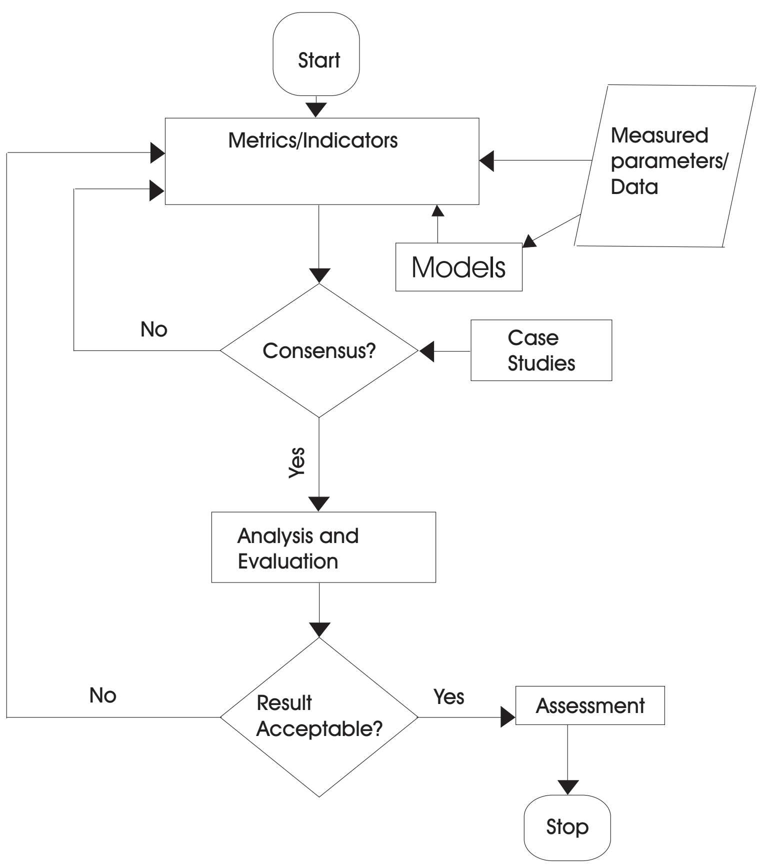
Figure 3. Strategic cyclical scaling at local, regional, and global scales.



Framework

All the methodological developments have to be executed within an agreed framework. Figure 4 provides such a conceptual framework.

Figure 4. A conceptual framework for executing SEA methodology.



The starting point of the methodological framework is to develop indices and indicators, as described in a previous section. It is of the utmost importance to have a consensus on these indices/indicators, i.e., the WDI; the variables and parameters that require measurement in order to compute the indices, i.e., the data; and the case studies that will be used to test the methodological development. The results obtained through this process should then be critically reviewed, and necessary methodological updates made accordingly. The synthesis of the results from this procedure would be reported in the assessment, which is expected to be a major policy-making document by the global decision making community.

What Kind of Information and Analyses Are Needed?

The comprehensive assessment will require information on irrigated area, water use, food production, employment, income, equity, institutions and ecosystem impacts and characteristics. Table 2 provides a sample of some of the datasets available. A variety of issues will be covered such as: trade, poverty, food security, livelihoods, groundwater mining, sustainability, efficiency, productivity, equity, environmental degradation/enhancement, biodiversity, public health, migration/displacement, water allocation, water scarcity, flood/droughts, and ecological services and sustainability.

Table 2. An overview of data sources for consideration in analyses.

Topic	Source/Reference	Comment/Description
World freshwater resources	Shiklomanov, IHP/UNESCO	Comprehensive data set on global surface water resources, and sectoral water use data, and monthly discharges of selected rivers in the world.
Composite runoff fields	UNH/GRDC	Global, basin, and station level runoff data.
FAO statistical databases	FAO	Time-series records covering international statistics on production, trade, food balance sheets, fertilizer and pesticides, land use and irrigation, forest products, fishery products, population, agricultural machinery, food aid shipments.
GEMS Water	UNEP	Global water quality data sets.
WHO Statistical Information System IWMI Atlas	WHO	Health and health-related statistical information from the WHO Global Programme on Evidence for Health Policy.

N.B. This is a selected listing of the data sources; data from national agencies are essential to carry out analyses at local scales.

Table 3 provides a linkage of the issue to be covered in the SEA and a measure of the importance of that issue at the different scales. This table should assist in allocating funding resources, etc.

Table 3. Relationship of issue to scale of analysis.

	Scale			
	Global	Regional	National	Local/
Trade	+++	+++	+++	++
Poverty	+++	+++	+++	+++
Food security	+	++	+++	+++
Livelihoods	+	++	+++	+++
GW mining		+	+++	+++
Sustainability	+++	+++	+++	+++
Efficiency		+	++	+++
Productivity	+++	+++	+++	++
Equity	+++	+++	+++	+++
Environmental degradation/ enhancement	++	++	+++	+++
Biodiversity	+++	+++	++	+
Public health	+	++	+++	+++
Migration/displacement	++	+++	+++	+++
Water allocation	+	++	++	+++
Water scarcity		+	++	+++
Flood/droughts		+	++	+++
Ecological services	+++	+++	+++	+++
Sustainability.	+++	+++	+++	+++

Note: +++ very strong ++ strong +some importance

Modeling Future Impacts

Modeling the Water Resources System

The Water Resources System is a complex interaction of the Natural Water and Earth System, the Human System, the Water Management System and Social/Institutional System. The water resources management system is a responsive system. It has to respond to variable hydrology from the Natural Water and Earth System, changes in water demands from the Human System, and changes in societal values regarding development and environmental protection from the Social/Institutional System.

While this is a comprehensive picture of the water resources system, it does not explicitly show the many driving forces that can potentially influence the system components. For example, population and economic growth will have an impact on the Human System and its interaction with the water resources system. Likewise, changes in societal values about sustainability, the environment, poverty and equity, coupled with changes in political systems will influence the Social/ Institutional System and its interaction with the water resources system. As we face the potential of greenhouse-gas-induced climate changes, the Water Management System is confronted with the possibility of changes in the mean values and increases in the variability of the climate variables affecting the Natural Water and Earth System. Changes are also possible in the other system components.

The goal of the modeling tasks in the SEA is twofold:

1. To derive variables needed for indicators from raw data where either the variable is a calculated parameter, e.g., the firm yield of a basin, or where the data do not exist, e.g., streamflow in an ungauged basin.

2. To develop a set of models that can provide quantitative assessments of the state of the future environment with and without the proposed actions. This includes responses of the water resources systems to scenarios of global change. These scenarios provide a combination of quantitative and qualitative projections of key economic, population, technological and institutional variables.

It is not feasible to build a single model that can address all the interactions between the water resources system component and the driving forces. Some models may model all the interactions, but at such temporal and spatial resolutions that physical meaningfulness is lost, while highly detailed spatial models can only model a single component of the systems. However, both types of models are useful tools when results are used with caution and in concert with expert judgement.

Who Will Do the Assessment?

The assessment will be carried out by an alliance of partners drawn from various backgrounds. At global and regional scales, possible partners include a variety of institutes with skills including impacts on ecosystems, food production and food security, trade and irrigation and water use.

Case studies will be done jointly by multidisciplinary groups drawn from various institutes. This collaboration is critical in that it will draw together people with very different viewpoints and help them to view the problems from different angles. Hopefully, this will help avoid the pitfall where one party uses case studies to “prove” a point.

How Will the Research Be Designed?

Research will be designed by a multidisciplinary core team that will set research protocols, monitor progress, and make sure outputs are pieced together. An initial workshop of interested parties will be held to give an overall framework for the analysis, and to form a small core team. The core team will be responsible for drawing terms of reference and engaging various parties in research.

What Data Will Be Needed?

The activity will update and integrate current knowledge by bringing together existing studies by IWMI, the World Bank and others on irrigation; plus impact analyses done by environmental organizations, such as studies on cost-benefits of systems without irrigation (benefits of wetlands).

Significant knowledge gaps will be bridged through new field research. One problem faced is that we do not have data on key pieces of information such as the extent of irrigated area, and the contribution of rain-fed versus irrigated agriculture to food production, and the contribution of groundwater to irrigated agriculture. The project will also be linked to IWMI's ongoing research, especially work that is being done in performance assessment, water accounting, poverty, gender, institutional analysis, environment and smallholder irrigation systems.

Initial Activities

The project can be broken into manageable pieces, then integrated again to form the comprehensive assessment. To start the project, some activities can already be identified.

1. *A Hindcast*. What would have happened without irrigation development over the last 50 years? As a first approximation, IWMI will use Podium to do this analysis. A target is to present initial results at the December meeting.

2. *Assessing Irrigated Area.* To address the knowledge gap, we propose to use remote sensing to get an idea of the present extent of irrigated areas in the world, including the intensity of irrigation.

3. *Groundwater.* What is the contribution of groundwater to food production? How much groundwater is depleted?

4. *Impact of Irrigation and Rain-fed Agriculture on Food Production.* On a regional basis, various partners will take the lead to find the impact of irrigation and agriculture on food production. This is an area where CG centers could take a lead.

5. *Impact on the Environment*. Various environmental partners would take a lead in assessing the impact of irrigation on environment by region. Potential partners for this are SEI or CEM (ex-IH Wallingford).

6. *Impact on Employment and Health.*

7. *Case Studies*. Case studies will focus on different issues for different regions done by multidisciplinary teams to cover a variety of issues. We will use case studies to look at past impacts, and to suggest future directions. For example, issues of focus are:

   - *Highly developed areas in South Asia, Southeast Asia and China.* How to increase yields on existing areas and avoid or solve problems of salinity and sodicity and overuse of ground water? How can the position of smaller farmers be improved?
   - *High potential areas such as the Mekong Basin or Eastern Indo-Gangetic Plains in India.* How many dams and large-scale systems are needed? What is the role of small-scale and traditional systems, particularly for women, poor and landless? How many wetlands remain, and how can biodiversity be protected?

- *High need areas in sub-Saharan Africa.* What is the role of full or supplemental irrigation for increased agricultural production? What are low-cost solutions focusing on small-scale farmers? What is the role of women, and the role of local communities in agricultural development? How can this development be done while maintaining biodiversity and ecosystems.

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