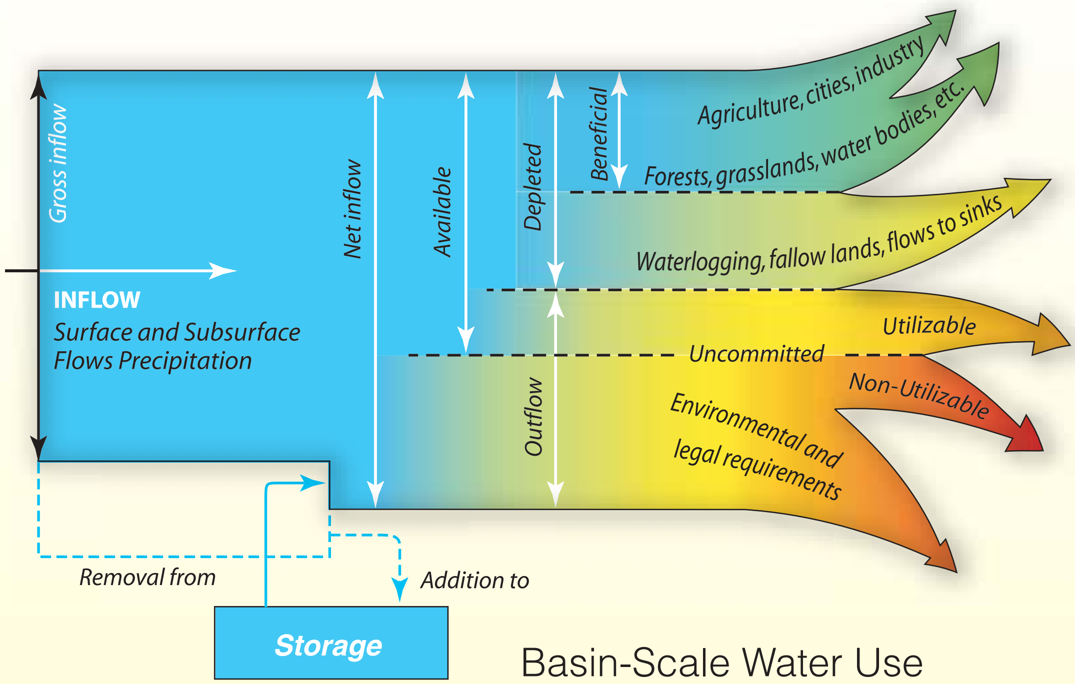
# Water Policy Briefing

Issue 8

Putting research knowledge into action


Basin-Scale Water Use

## Improving Water Productivity:

# How do we get more crop from every drop?

Agriculture currently consumes 70% of the world's developed fresh water supplies. By improving the productivity of water used for agriculture by 40%, it is possible to reduce the amount of additional freshwater withdrawals needed to feed the world's growing population to 0.

What steps can policy makers take now? And where should we invest in research for the future?

Comprehensive Assessment of Water Management in Agriculture

# How Do We Get More Crop from Every Drop?

If current trends continue, the water crisis—which is already beginning to rear its head in many countries through depleted groundwater aquifers, dried-up rivers and wetlands, and frequent water shortages—will indeed become a global problem.

A recent study by the International Food Policy Research Institute (IFPRI) and the International Water Management Institute (IWMI) projects that if present trends continue, by 2025 competition from growing cities and industry worldwide will limit the amount of water available for irrigation, causing annual global losses of 350 million metric tons of food production—slightly more than the entire current U.S. grain crop. The environment will also sustain further damage, as water from this already thirsty sector is diverted to agriculture, households and industry. If levels of investment in sustainable water policy and management decrease over the next 20 years, the result will be major declines in food production and skyrocketing food prices.

Research done over the past decade shows that by improving the productivity of water on irrigated and rain-fed lands, we can have enough water for cities, industry and nature. But this requires a commitment to institutional and management reforms, and substantial investment in crop research, technology, and infrastructure.

## Why growing more food with less water is the key to solving the water crisis

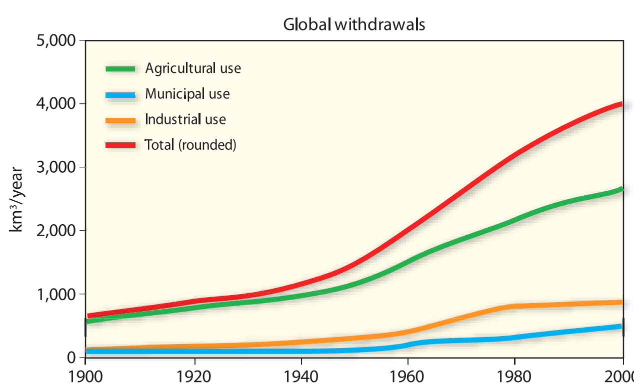
In some areas salinization and rapidly declining water tables are symptoms of the water crisis. In many, dried-up rivers and degraded aquatic ecosystems are the most pressing problem. In Central Asia, irrigated cotton uses nearly the entire flow of the Amu Darya and Syr Darya. The Yellow river did not reach the sea for 7 months in 1997 due to increases in upstream water use. Similarly, very little Nile, Indus, or Colorado river water reaches the sea.

In spite of development of water resources intended for food production, malnutrition persists, mostly in South Asia and sub-Saharan Africa. Small farmers and the poor are particularly water-deprived and in situations of water scarcity they are the hardest hit. This is particularly true in regions dubbed "economically water scarce," meaning that while there is water available, there are no financial resources to harness it for human use.

Improving the productivity of water used in agriculture is the key to solving these problems. Getting more crop per drop enhances food security and makes more water available for nature, industry and domestic users. It enables us to reduce the need for investments in new water storage and irrigation infrastructure—investments many countries can't afford. By improving the productivity of water on rainfed lands, we can contribute to the food security and incomes of some of the world's poorest people.

Many people associate water savings with municipal water use—encouraging domestic users to practice water conservation and cities to plug up leaking supply systems. While these efforts have localized benefits, it is important to realize that cities actually consume very little of the world's water. Even in developed countries

**Water use by sector**




Source: Based on data from Shiklomanov, *Water International*, March 2000.

This issue of *Water Policy Briefing* is based on research presented in the book *Water Productivity in Agriculture: Limits and Opportunities for Improvement* edited by J.W. Kijne, R. Barker and D. Molden. It brings together research thinking by partners in the Comprehensive Assessment of Water Management in Agriculture. For information on ordering the book, please write to comp.assessment@cgiar.org or visit the program's website: www.iwmi.org/assessment.

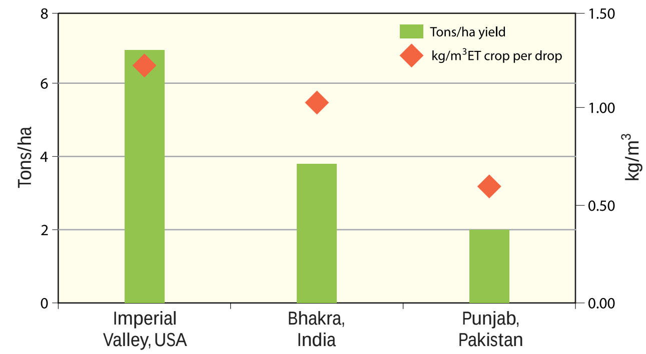
where most households have easy access to municipal water supplies, a person uses less than 150 liters of water per day. Compare this to the 2,000 to 5,000 liters of water required to produce enough food to feed one person one day and you begin to understand why finding ways of getting more crop per drop is vital to the world's future.

Another common misperception is that enormous amounts of water are wasted in irrigation—water 'down the drain.' In fact, much of the waste is recaptured by farmers, used by trees or ecosystems, recharges groundwater or it flows back into the river system to be used further downstream. The real problem is that in water-scarce areas farmers as a group have become if anything too efficient at converting water into crop production resulting in dried-up and polluted rivers. Getting more crop per drop—improving water productivity—will ensure food security and sustainable agricultural production. In water-stressed areas, this is often the only option.

## How much scope is there for improving water productivity?

In many areas, potential productivity is not realized in part due to poor irrigation management. Considering the productivity of water in more than 40 irrigation systems worldwide, an IWMI study demonstrated a 10-fold difference in the gross value of output per unit of water consumed by crops. Some of this difference is due to environment, or the price of grain versus high-valued crops. But even among grain-producing areas, the differences are large. Improving performance of poorly managed irrigated agricultural systems should be a high-priority action.

**Comparison of yields and water productivity of wheat in USA, Pakistan and India**




### Recommendations for policy makers

- Before investing in expanding irrigated area, look at options for improving productivity.
- Take a basin perspective on water savings and understand how changes in water management or allocation in one area affect users in another.
- Integrate management of 'blue' water—from rivers and reservoirs—with green water—rainfall stored in the soil profile or in aquifers.
- Invest in efforts to provide reliable irrigation to farmers in existing schemes.
- Create policies and incentives to support the uptake of technologies and practices that will improve water productivity and reduce degradation of agro-ecosystems.
- Ensure that the poor benefit from investments in improving water productivity by ensuring access to water for income-generation, developing and promoting affordable water-productivity-enhancing technologies, and giving the poor a voice in water decisions

Managing water in agriculture should not exclusively focus on improving the productivity of the 2,500 km$^3$ of water diverted to irrigation, but must also include improving the productivity of the 16,000 km$^3$ used in rain-fed agriculture. Rain-fed agriculture contributes to about 60 percent of cereal production on 70 percent of the global cereal area. It is the primary means of food production in most countries, and the only means of production for many farmers. Consequently, a one-percent increase in rain-fed cereal production would have one and half times more effect than a similar productivity increase in irrigated cereal production. Improving the productivity of rain-fed lands also has the potential to benefit some of the world's poorest people—people who currently struggle to farm marginal rain-fed lands and are at the mercy of droughts.

## Paths to improving productivity

What actions are needed? There are a variety of interconnected paths that can improve the productivity of water. No single path holds the answer. To be successful we must develop integrated strategies tailored to the needs of specific regions and river basins.

### Crop breeding

Crop breeding over the last century has indirectly increased the productivity of water by increasing yields without increasing crop water demand. The focus has primarily been on getting more yield per unit of land. It is only in the past decade that attention has turned to producing crops that can yield more with less water, withstand water-scarce conditions, and thrive on low- quality (saline/alkaline) water. Scientists have already identified traits and genes for drought- and salt-tolerance in a number of crops. For some crops, conventional and molecular breeding techniques are expected to yield results within five years (see table 1). The Future Harvest Centers of the CGIAR have already released drought-tolerant varieties of several crops for evaluation by collaborating institutes and farmers. Crops include: rice (IRRI, WARDA), maize (CIMMYT), wheat (CIMMYT, ICARDA), barley (ICARDA), cowpea (IITA), groundnut (ICRISAT), lentil (ICARDA), and sweet potato (CIP).[1]

**Table 1. Genetic approaches to increasing crop water productivity**

| Water productivity factor | Genetic approach | Probability of major progress in 5 years |
|---|---|---|
| Minimize non-transpirational uses of water | Herbicide-resistant crop | low* |
| | Weed competitiveness | low |
| | Heat and cold tolerance at flowering | medium |
| | More efficient cooling via evapotranspiration | medium |
| | Nitrogen-use efficiency | medium |
| | Nitrogen fixation | low |
| Reduce water consumption without reducing production | Waxy cuticle production | medium |
| | Rapid stomatal closure | high |
| | Cooling mechanism for leaves | high |
| | Rapid canopy closure | low |
| | Thicker, more intact casparian strip | high |
| | Sustainable production of aerobic rice | medium |
| Increase production without increasing water consumption | Short duration, seedling vigor | high |
| | Higher harvest index | medium |
| | C4 photosynthesis | medium |
| | More photosynthesis per unit water transpired | low |
| | More dry matter allocated to grain after stress | medium |
| | Stay-green flag leaf | medium |
| Use lower-quality water | Tolerance of salinity | high |
| Less water management | Tolerance of waterlogging | medium |
| | Tolerance of submergence | high |

*Transgenic mechanism is currently available but its deployment is problematic.

The probability is considered high where progress has already been made towards identifying regulatory genes. The probability is considered medium where some of the genes of a relevant pathway have been isolated. The probability is considered low where little or no relevant data exist.

Source: Bennett in *Water Productivity in Agriculture*, 2003.

## Reducing land degradation

Land and water degradation constrain efforts to improve water productivity. Soil erosion, for example, reduces not only soil's depth but also its capacity to hold water and the amount of nutrients it contains. There is a common misperception that degradation of the agro-ecosystems is a slow process that can be always reversed with adequate inputs such as fertilizer. But ecosystems are resilient only up to a certain threshold, and can collapse when pushed too far. In many cases, farmers need incentives to make long-term investments in soil conservation practices—particularly when results from such investments do not have a direct or significant impact on their incomes. Social and institutional factors, such as land tenure, also affect farmers' willingness to invest.

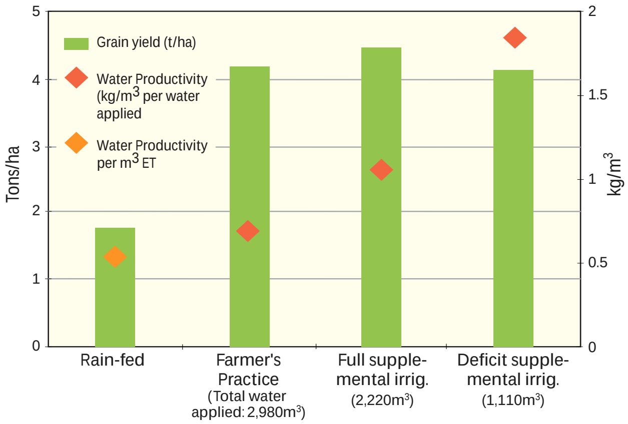
## Supplemental and deficit irrigation and water harvesting for rain-fed areas

Supplemental irrigation combined with on-farm water-harvesting practices, such as mulching or bunding, reduces vulnerability to drought and helps farmers to get the most out of the scarce resources. Mitigating the effects of short-term drought is a key step in achieving higher yields and water productivity in rain-fed areas.

Farmers are unwilling to risk investments in productivity-enhancing inputs, such as fertilizers and higher-yielding crop varieties, when their water supply is uncertain. In sub-Saharan Africa farmers run the risk of total crop failure due to drought once every five years and severely reduced yields once every two years. Studies by IHE-UNESCO suggest that with significant investments in water harvesting, conservation tillage

[1] IRRI - International Rice Research Institute
WARDA - West Africa Rice Development Association
CIMMYT - Centro Internacional de Mejoramiento de Maiz y Trigo (International Maize and Wheat Improvement Center)
ICARDA - International Center for Agricultural Research in the Dry Areas
IITA - International Institute of Tropical Agriculture
ICRISAT - International Crops Research Institute for the Semi-Arid Tropics
CIP - Centro Internacional de la Papa (International Potato Center)

**Comparison of yields and productivity for rainfed, irrigation and supplemental irrigation**




Source: Based on data provide by Oweis & Hachum in *Water Productivity in Agriculture*, 2003.

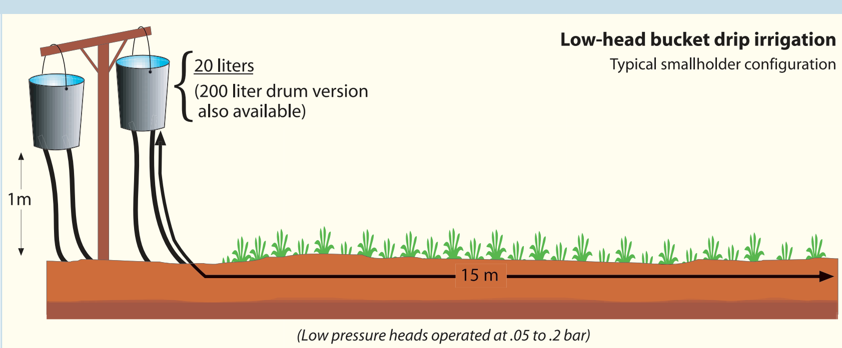
and supplemental irrigation during short dry spells, yields of staple food crops could be more than doubled in many areas of sub-Saharan Africa.

Deficit irrigation—a strategy which maximizes the productivity of water by allowing crops to sustain some degree of water deficit and yield reduction—holds promise for severely water-short areas, such as North Africa and the Middle East. ICARDA studies in Syria have shown that applying 50 percent of the supplemental irrigation requirement only reduces yields by 15 percent. For deficit irrigation to function as a realistic strategy, we need to better understand the relationship between yield and water deficit and we need to identify the types of support and incentives that farmers need to adopt the practice.

## Low-cost technologies

Various forms of precision irrigation—mainly sprinkler, drip irrigation systems and dead-level basins—can increase yields over good but ordinary irrigation systems by 20 to 70 percent, depending on the crop and other conditions, and they do so with much less water diverted to the crop. In South Asia and Africa, very low-cost bucket and drip sets are becoming increasingly popular with farmers. In areas where shallow groundwater is plentiful, thousands of poor farmers in Bangladesh have used low-cost treadle pumps to supply water for crops for their own food security and for additional income. But we do not yet understand the potential, or the mechanisms, for large-scale uptake of these technologies.

Low-cost technologies like the bucket and drip kit are helping small farmers in Africa and Asia increase their yields, improve household incomes and make the most productive use of scarce water.




## Improved irrigation management practices

Perhaps the most important basic principle in irrigation is to deliver a reliable supply of water. In an uncertain environment, farmers will not invest in seeds, fertilizers, and land preparation, and consequently yields and water productivity will suffer.

A second basic principle has to do with timing. At various times in a crop's growth cycle, water stress can be particularly damaging. Tube-well irrigation systems in India typically produce yields that are twice as much as those from canal irrigation systems. Tube-well water is reliably available virtually on the farmer's demand while in most Indian canal systems farmers must wait for their turn which may not match crop needs. Similarly, the Chinese "melons-on-the-vine system" of canals feeding small tanks places water closer to the fields and lets farmers store water and apply it when it is needed.

## Integrating recycling and reuse into basin and irrigation management

Water reuse is already becoming an integral part of water management in many water-scarce areas. For example, it is common practice for farmers in Egypt and North China to place small pumps in drainage ditches to reuse water. The irrigation agency supports this reuse strategy by blending drainage water with freshwater to increase the useable supplies. Millions of farmers in Indo-Gangetic plains employ shallow tube wells to recycle the water that percolates through the soil layer—effectively capturing and using water before it flows out of the basin. This practice also gives farmers more control over the amount and timing of irrigation applications—with dramatic effects on yields.

Many farmers in peri-urban settings rely on wastewater from cities for their crops. Irrigating with low-quality water is often the only option; but even when farmers do have access to canal irrigation, many prefer wastewater because they are guaranteed a constant supply, and the nutrients the water contains allow them to save on fertilizer. Pollution and health risks should be considered when crafting reuse strategies. The problem is that in many cases reuse is an unregulated individual or community initiative—often ignored by water management agencies. This leads to suboptimal situations in terms of degradation of water quality, human health, and water productivity.

## Agronomic and field practices

Conservation or zero tillage, optimal fertilizer and water application, and other forms of soil-water management can raise productivity of water. Practices appropriate for small farmers have already been identified in many areas (see table 2). Here the challenge is to find the right mix of policies and incentives to encourage large-scale uptake.

## Integrated natural resources management within basins

Within farms—irrigation systems, and river basins, livestock, fish, and forests all have important water needs and implications. Integrating aquaculture into irrigation or examining the trade-offs between crop water use and water for fisheries or forests is a means of providing more food and nutrition per unit of water.

### Table 2. Summary of the agronomic practices

| Category/ Item | Comments | Constraints to adoption |
|---|---|---|
| | **WATER-RELATED** | |
| Alternate row irrigation | Suitable for row crops, depends on irrigation system. | Requires more labor & management than conventional furrow irrigation. |
| Minimize pre-planting irrigation | | Requires control over irrigation supply. |
| Minimize time between pre-planting irrigation & planting | Especially with rice. | Requires control over timing of irrigation; availability of labor & farm machinery factors. |
| | **SOIL-RELATED** | |
| Reduced (or conservation) tillage | | Cost, availability & maintenance of machinery. |
| Zero tillage | Placing seed on saturated soil without tillage. | Unless the field is level, yields may be less. |
| Raised beds or broad beds & furrows | | Requires tools, also labor requirement if beds have to be remade each season. |
| Row spacing & orientation | Affects interception of radiation, & if planting is on contours, reduces runoff. | Requires flexible seed drill; may be more labor-intensive. |
| Land leveling | Prevents ponding & unequal application of water. | Requires skilled labor & machinery; needs to be repeated every 2-3 years. |
| Mulching & residue management | Lowers evaporation from soil surface & reduces runoff. | Gravel mulches, etc., are expensive. |
| Application of organic matter (OM) | Increases water-holding capacity of soil. | OM is scarce & often used for other purposes, e.g., as fuel; needs to be repeated often as OM in semiarid tropics decomposes quickly. |
| | **PLANT-RELATED** | |
| Direct seeding of rice | Often done to reduce labor rather than to increase water productivity. | May have more diseases, insect & weed problems &, hence, give lower yields. |
| Timely planting, etc. | Timely sowing, weed control, fertilizer application, nutrient management & best crop rotation raise yields. | Requires good farming skills & extension services; labor-intensive. |

Source: Kijne in *Water Productivity in Agriculture*, 2003.

In addition to their role as water users, trees and livestock impact land and water interactions within a basin. Overgrazing or clearing forests for agricultural development or lumber can hasten runoff and sedimentation—detrimental to both upstream and downstream uses. Integrating these production systems within a basin management framework can reduce degradation and improve productivity.

## The role of policy, institutions and incentives

For any of these strategies to work requires the right set of incentives and support for all the actors involved—a function of policies and institutions. Existing institutions for water management need incentives to be more efficient and to offer services that will support improvements in water productivity. Farmers need incentives to adopt technologies and practices to make the most of the water they use.

Taking narrow sectoral approaches to water management should become a thing of the past. Especially as competition for water becomes more intense, how water is managed in once sector often impacts its availability in others. Laws, regulations and organizations should be defined to encourage water management from a basin perspective.

Another area which should be targeted for reform is subsidies and pricing. In many cases, poorly designed subsidies can actually discourage farmers from getting the most crop per drop.

### Where is more research needed?

- Crop breeding for drought-tolerance, water conservation, and ability to thrive on low-quality water.
- Understanding the interaction between water management practices at different levels—field, system, basin.
- Co-managing water for agriculture and the environment.
- Appropriate pro-poor technologies and practices for improving water productivity at field and system levels.
- Policies and incentives needed to implement water-saving technologies and practices.
- How to manage irrigation water for multiple uses—for crops, for domestic use, for other income-generating activities.
- Tools and models to support responsible decision making for valuing the productivity of water in its various uses and examining trade-offs.

### A basin perspective on water savings

Essentially, real water savings means freeing up water from non-beneficial uses and providing it to another more productive use. In agriculture, we would like to increase production, and yet be able to release water for the environment, cities, or industries.

Two easy targets for reducing non-beneficial depletion—taking care that these are not already serving important environmental functions—are:

- Reducing flows to sinks—for example, deep or saline aquifers from which the water cannot be economically recovered.
- Reducing non-beneficial evaporation—for example, from fallow fields or waterlogged areas.

In some cases, improving irrigation efficiency is the most appropriate way to reduce non-beneficial depletion—to save water. But a common mistake is to look at water savings only from the narrow point of view of irrigation efficiency at the farm or irrigation-system level—ignoring the larger basin phenomena of water recycling and multiple uses of irrigation water that are prevalent in many systems. For example, seepage 'losses' from canals and fields may recharge aquifers and shallow dug wells used for domestic water supply. Irrigation drainage water is often captured and reused by farmers or it reenters the river system to be used downstream.

Failing to take a basin perspective when implementing water conservation strategies, not only runs the risk of not saving water but can also have a negative impact on water quality, drinking water supply, groundwater balance, and downstream human and ecological users.

Increases in water productivity are necessary to solve many of the problems of the water crisis, but they are not sufficient. It is imperative that these be accompanied by a poverty focus to help the poor reap the gains of increases in water productivity. Attention needs to be given to establishing and maintaining access to water for domestic uses and income-generation, affordable water-productivity-enhancing technologies, and giving the poor a voice in water decisions.

Whose responsibility is it? Increasing water productivity requires the coordinated set of actions from a range of people: policy makers, resource managers, farmers, fishermen, and water managers; researchers from agronomy, water resources, irrigation, and natural resources management; and in fact all of us who care about influencing policies about how water is used.

## Water Policy Briefing Series

The *Water Policy Briefing* Series translates peer-reviewed research findings into useful information for policy makers and planners. It is published several times yearly, with the goal of bringing new and practical approaches to water management and planning into the policy recommendation process.

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## The Comprehensive Assessment of Water Management in Agriculture

The Assessment is the first international research and capacity building program to take stock of the costs and benefits of the past 50 years of water development for agriculture, the water management challenges communities are facing today, and solutions people have developed. The results of this research will enable farming communities, governments and donors to make better-quality investment decisions to meet food and environmental security targets in the near future and over the next 25 years.

The Comprehensive Assessment of Water Management is done by a coalition of partners which includes 11 Future Harvest agricultural research centers supported by the Consultative Group on International Agricultural Research (CGIAR), the Food and Agriculture Organization of the United Nations (FAO), and partners from some 40 research and development institutes globally.

The Assessment is supported by the governments of the Netherlands, Switzerland, Taiwan, Australia and the Rockefeller Foundation with in-kind contributions from many of the participants.

Further information is available on-line at: **www.iwmi.org/assessment** or write to comp.assessment@cgiar.org

## Participants in the Comprehensive Assessment of Water Management in Agriculture:

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