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Comprehensive assessment of water management in agriculture

water for food, water for life

# Insights

## from the Comprehensive Assessment of Water Management in Agriculture

Stockholm World Water Week, 2006

# Insights from the Comprehensive Assessment of Water Management in Agriculture

International Water Management Institute (IWMI), Colombo, Sri Lanka

## ABOUT THE COMPREHENSIVE ASSESSMENT

Views diverge over choices about water, food and ecosystems. Some emphasize that developing more water through large infrastructure will relieve scarcity, fuel economic growth and relieve pressure on the environment. At the other end of the spectrum are those who call for a halt to expanding agriculture and hydraulic infrastructure and for practices that restore ecosystems to their original balance. Widening the divergence of positions are differences in the language and approaches used to describe the tensions and trade-offs.

The Comprehensive Assessment of Water Management in Agriculture was conducted to bring these diverse views together—to critically evaluate the current situation and to provide policy-relevant recommendations on the way forward.

The Assessment evaluates the benefits, costs and impacts of the past 50 years of water development, the water management challenges that communities face today and the solutions that people have come up with to meet those challenges. It is the product of a multi-institute process assessing the best knowledge and stimulating the best thinking on ways to manage water resources to increase food production, to reduce poverty and food insecurity and to enhance environmental sustainability.

The Assessment creates a common agenda for the agricultural and environmental communities. Its findings should enable better investment and management decisions in water and agriculture in the near future, on the way to the Millennium Development Goals for 2015 and over the next 50 years.

## THIS REPORT

The report contains findings of the Comprehensive Assessment of Water Management in Agriculture to be presented and discussed at the World Water Week in Stockholm, 2006. The assessment results will be published in late 2006.

The Comprehensive Assessment (www.iwmi.cgiar.org/assessment) is organized through the CGIAR's Systemwide Initiative on Water Management (SWIM), which is convened by the International Water Management Institute. The Assessment is carried out with inputs from over 100 national and international development and research organizations—including CGIAR Centers and FAO. Financial support for the Assessment comes from a range of donors, including core support from the Governments of the Netherlands, Switzerland and the World Bank in support of Systemwide Programs. Project-specific support comes from the Governments of Austria, Japan, Sweden (through the Swedish Water House) and Taiwan; Challenge Program on Water and Food (CPWF); CGIAR Gender and Diversity Program; EU support to the ISIIMM Project; FAO; the OPEC Fund and the Rockefeller Foundation; and Oxfam Novib. Cosponsors of the Assessment are the: Consultative Group on International Agricultural Research (CGIAR), Convention on Biological Diversity (CBD), Food and Agriculture Organization (FAO) and the Ramsar Convention.



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## PRODUCING FOOD—SUPPORTING LIFE

Imagine a channel of water a meter deep, a kilometre wide, and 7 million kilometres long—long enough to encircle the globe 180 times. That's the prodigious amount of water it takes each year to produce 3,000 calories of food a day for each of the world's 6.1 billion people.

Broken down into smaller quantities, a calorie of food takes a liter of water to produce. A kilo of grain takes 500-4,000 liters, a kilo of industrially produced meat 10,000 liters. Surprising numbers, indeed. Add 2-3 billion people by 2050 and accommodate their changing diets from cereals to more meat, and that will add another 5 million kilometres to the channel of water needed to feed the world's people.

Where will that water come from? Will it reach the poor and hungry? Will it produce enough food? Will it continue to sustain the environment? This Assessment finds that there is enough land, water and human capacity to produce enough food for a growing population over the next 50 years, so in this sense the world is not 'running out' of water.

But the Assessment also finds a multitude of water, food and environmental issues that add up to a crisis. Water is a constraint to acquiring food for hundreds of millions of people. Important aquatic and terrestrial ecosystems are damaged or threatened. The competition for scarce water resources is intense. And in many basins there is not enough water to meet all the demands—or even for rivers to reach the sea. These local problems could grow in number and severity, or shrink, depending on whether and how they are addressed.

What is clear is that today's water management challenges—and tomorrow's—differ greatly from those of 50 years ago, or even 25, and thus require new approaches. Those approaches will be broader, looking into the opportunities in rainfed, irrigated, livestock and fisheries systems—and in preserving, even restoring, ecosystems. They will build water systems for many purposes and manage them to provide a wide range of ecosystem services. They will be more participatory and involve informed multi-stakeholder dialogues to deal with the many trade-offs. And they will embrace diverse interests and institutions to increase the equity of water's use. These are the hopes emanating from this Assessment of water for food and for life.

## TRENDS PROMISING—AND DISTURBING

Investments in water for agriculture over the last 50 years have delivered enormous benefits, but at severe intended and unintended costs.

### *Promising trends*

- A steady increase in the per capita consumption of food, leading to better nutrition for many and a decrease in famines. The average global calorie intake increased from 2,250 kcal in 1961 to 2,800 kcal in 2000, enough to feed the world in spite of a growing population
- A steady increase in land and water productivity—with average grain yields rising from 1.4 tonnes a hectare to 2.7, during the past four decades and significant gains in water productivity (figures 1 and 2).

- An increase in global trade in food products and consequent flows of virtual water (the water embodied in food exports) offering prospects for better national food security and the possibility to relieve water stress.

***Very disturbing trends***

- The average calorie intake in South Asia (2,450 kcal) and sub-Saharan Africa (2,230 kcal) remains far below norms (3,000 kcal).
- Pollution and river desiccation are increasing because of greater agricultural production and water consumption. Fisheries, important for the livelihoods of rural poor, have been damaged or threatened.
- In many basins water resources are overcommitted because of over-expansion of irrigation facilities generating scarcity.
- Groundwater levels are declining rapidly in densely populated areas of North China, India and Mexico because of overexploitation.
- Land and water resources are being degraded through erosion, pollution, salinization, nutrient depletion, and the intrusion of seawater.
- Water management institutions have been slow to adapt to new issues and conditions.
- Subsidies continue to distort water and agricultural practices in developing and developed countries.

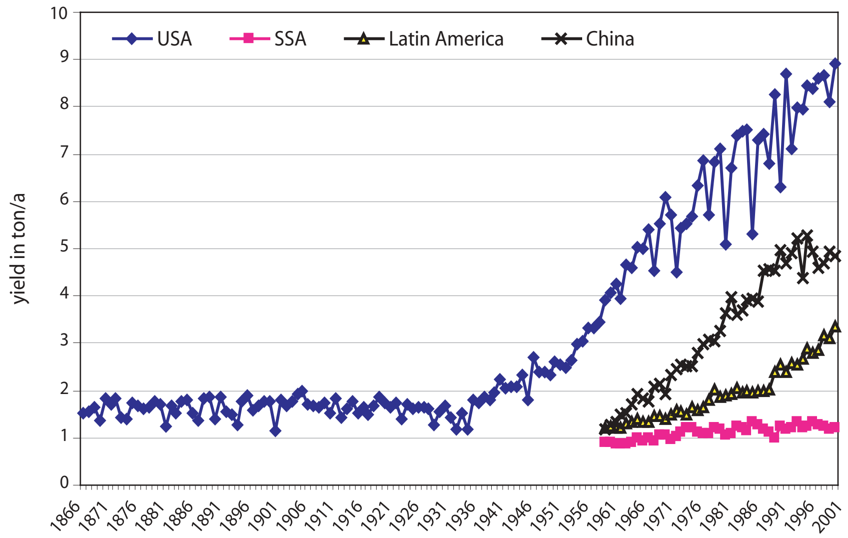
***Double-edged trends***

- Increasing withdrawals for irrigation in developing countries have been good for economic growth and poverty alleviation, but bad for the environment.
- The growing demand of cities and industries for water offers possibilities for employment and income, but it also shifts water out of agriculture, puts extra strain on rural communities and pollutes water.
- Fish and meat consumption is rising, increasing the reliance on aquaculture and industrial livestock production, with some positive wellbeing and income benefits but greater pressure on water resources and the environment.

***And emerging forces***

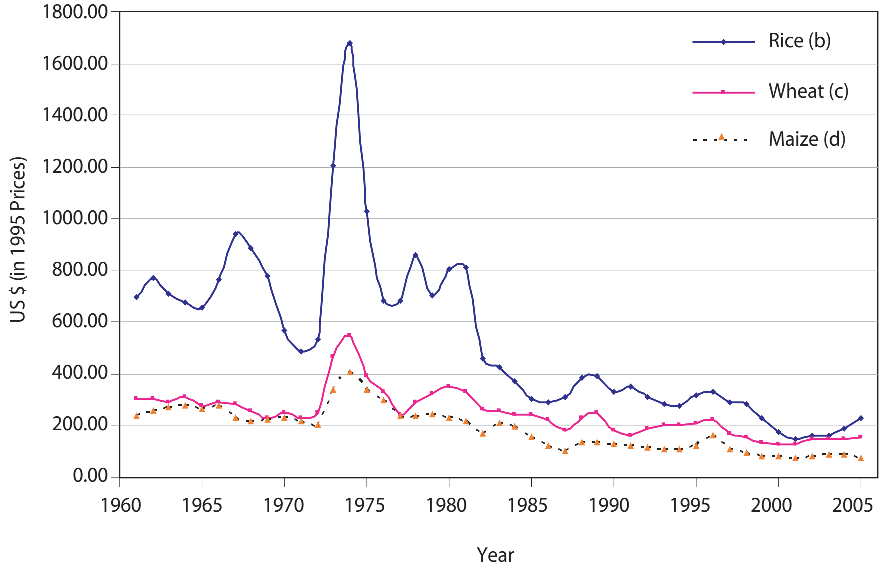
- The climate is changing, which will affect existing temperatures and patterns of precipitation. Agriculture nearer the equator—where most poor countries are situated—will be affected most.
- Urbanization increases the demand for water, generates more wastewater and changes patterns of demand for agricultural products, all affecting agricultural practices.

**Figure 1. Maize yield in selected countries and regions. How long before sub-Saharan Africa takes off?**




*Sources:* Analysis based on FAO and USDA data

**Figure 2. Trends in food prices**




*Sources:* World Bank data

- Energy prices are skyrocketing—with implications for the costs of pumping water, applying fertilizers, and transporting products—and globalization continues to extend its reach.
- Perceptions and thinking about water are changing, with more attention to green water resources (in the soil), not just to blue water resources (in lakes, rivers and aquifers). More attention is also going to ecosystem and integrated approaches and to understanding how forces outside water for agriculture influence both water and agriculture.

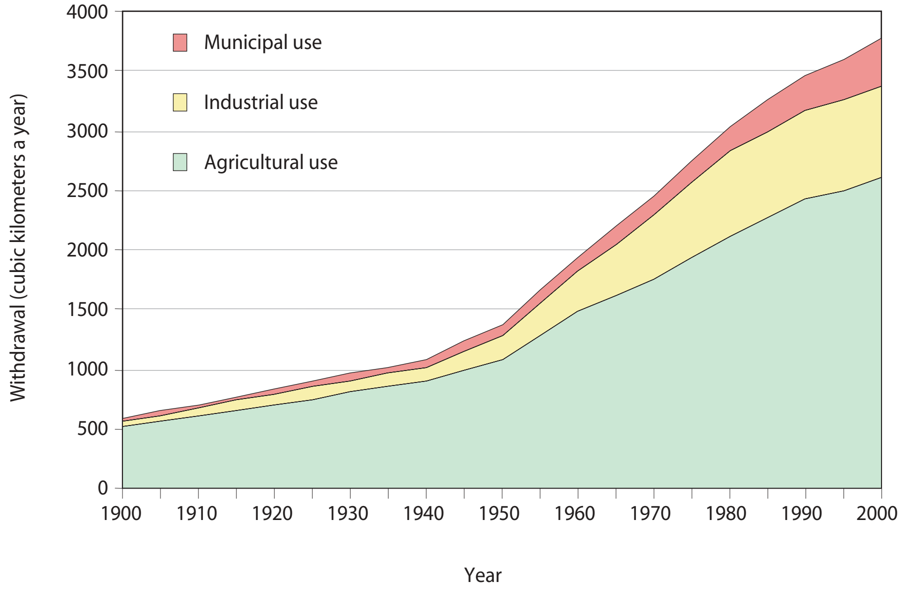
## WATER USE TODAY

Agriculture is the dominant water user, but the part diverted for domestic and industrial use is growing rapidly.

### Withdrawals for agriculture (74%), industry (18%) and municipalities (8%)

Total global blue water withdrawals are estimated at 3,390 km$^3$, with 2,490 km3 (or 74%) for agriculture, mostly irrigation (figure 3). About 20% comes from groundwater, mostly for drinking water and irrigation. Industrial and domestic use is growing relative to that for agriculture. And water for energy generation – hydropower and thermo cooling – is growing rapidly. Not all water withdrawn 'lost.' Much is available for reuse in river basins, but often at degraded quality.

**Figure 3. Rapidly increasing withdrawals of blue water for human use, mostly agriculture**




Based on Shiklomanov, I., IWRA Water International Vol 25 (1), March 2000

Per capita water withdrawals are highest in OECD countries, where industrial water use is high, and in the Middle East and North Africa, where irrigated agriculture is a main water user. In Sub-Saharan Africa withdrawals are only a tenth of those in the OECD, with little water developed for agriculture. But the variation is huge. In the Zambezi basin less than 1% of the total water resources are withdrawn for human purposes. In the Limpopo basin most water is allocated, and the basin is closing.

Food production consumes an enormous amount of water. In 2000 an estimated 7,200 cubic kilometers of water was depleted by crop evapotranspiration – the conversion of liquid water to vapour to support plant growth – to produce the global food and feed for 6.1 billion people. This roughly corresponds to 3,000 liters of water to feed one person for one day, or 1 liter of water to produce 1 calorie.

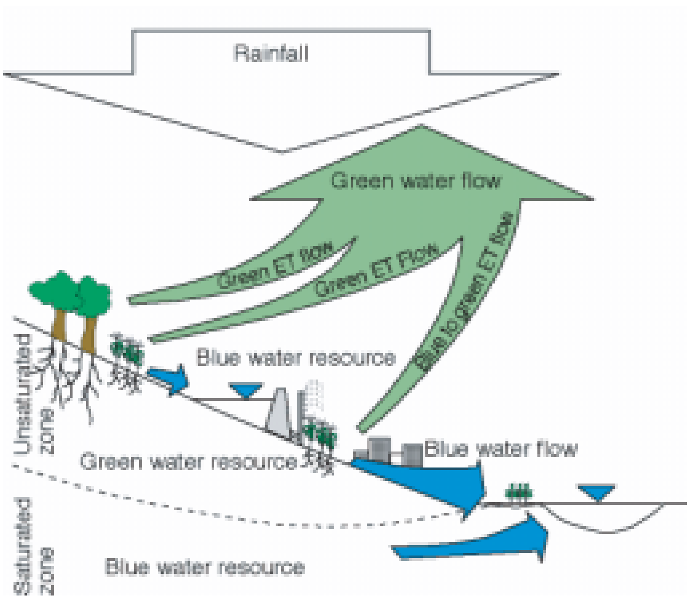
**Box 1. Green and blue water in rainfed and irrigated agriculture**

*Rainfall produces two categories of freshwater: green and blue.*

Green water is the soil moisture generated by rainfall and available for root water uptake by plants. It is the main water resource for rainfed agriculture.

Blue water is the stored runoff of rainfall in dams, lakes, wetlands and aquifers. It is the main water resource for irrigated agriculture. It flows back to the atmosphere through evaporation, interception and transpiration by plants.

Green water flows take 65% of global precipitation, blue water flows 35%. About 9% of total blue water flows are withdrawn for agriculture, and 11% of green water flows support crop and livestock production.




(*Source:* Stockholm Environment Institute)

More than 80% of crop evapotranspiration comes directly from rainfall and about 20% from irrigation water diverted from rivers and groundwater (figure 4). In the Middle East and North African region, where rainfall is low and unreliable, more than 60% of crop evapotranspiration comes from irrigation; in Sub-Saharan Africa, less than 5%.

**Map 1. Green water accounts for 80% of crop use, irrigated water 20%, with big regional variations.**

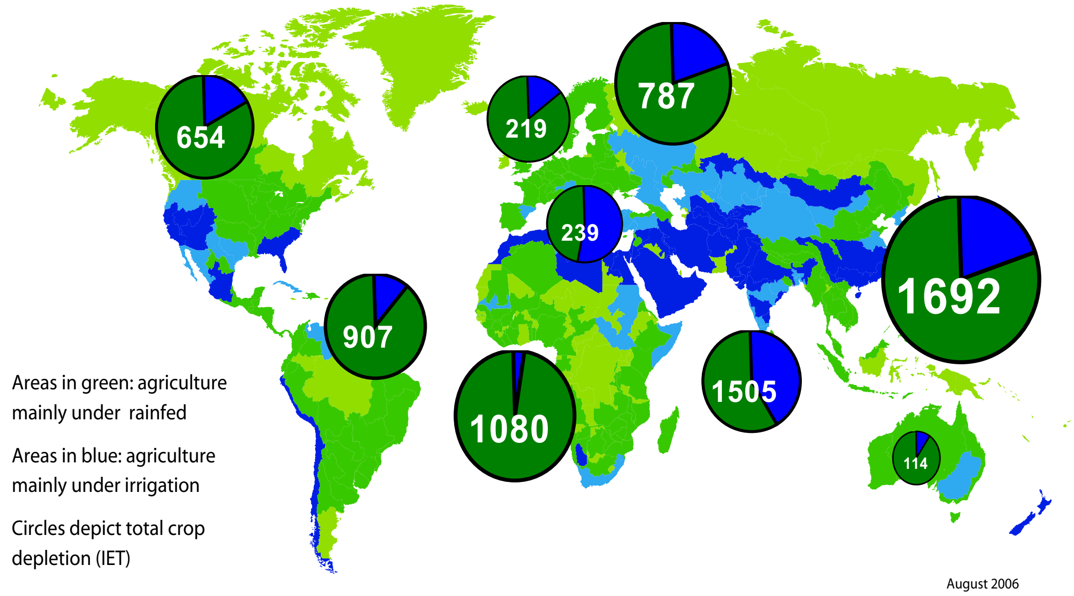
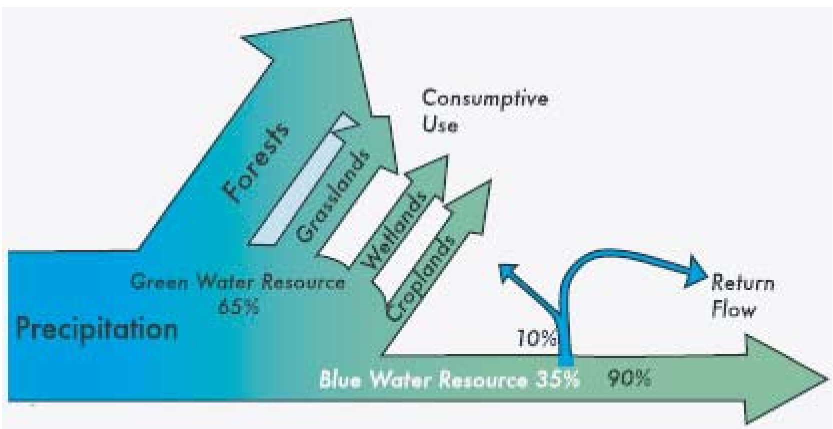



**Figure 4. Global water balance**




*Source:* From Stockholm Environment Institute (SEI) and Stockholm International Water Institute (SIWI)

## WATER SCARCITY TODAY

A quarter of the world's people live in areas characterized by physical water scarcity. One billion live in basins that face economic scarcity, where human capacity or financial resources are likely to be insufficient to develop adequate water resources (map 2). What's behind today's water scarcity? A lack of finance. A lack of human capacity. A lack of adaptive institutions. And a lack of good governance.

Access to water is difficult for millions of women and men for reasons that go beyond the physical resource base. In some places, water is abundant, but getting it to where people can use it is difficult. In other places, people's demands go beyond what the natural resource base can handle, and not everyone has assured access to water.

### Economic scarcity

Economic scarcity occurs when there is a lack of investments in water or lack of human capacity to keep up with growing water demand. Much of the scarcity for people is due to the way institutions function, favoring one group over another, not hearing the voices of various groups, especially women. Symptoms of economic water scarcity include little small or large infrastructure development so that people have trouble getting enough water for agriculture or even drinking; or inequitable distribution of water even though infrastructure exists. Much of sub-Saharan Africa is characterized by economic scarcity, where further water development could ease poverty problems. Many small pockets exist throughout the globe where institutions struggle to equitably distribute resources.

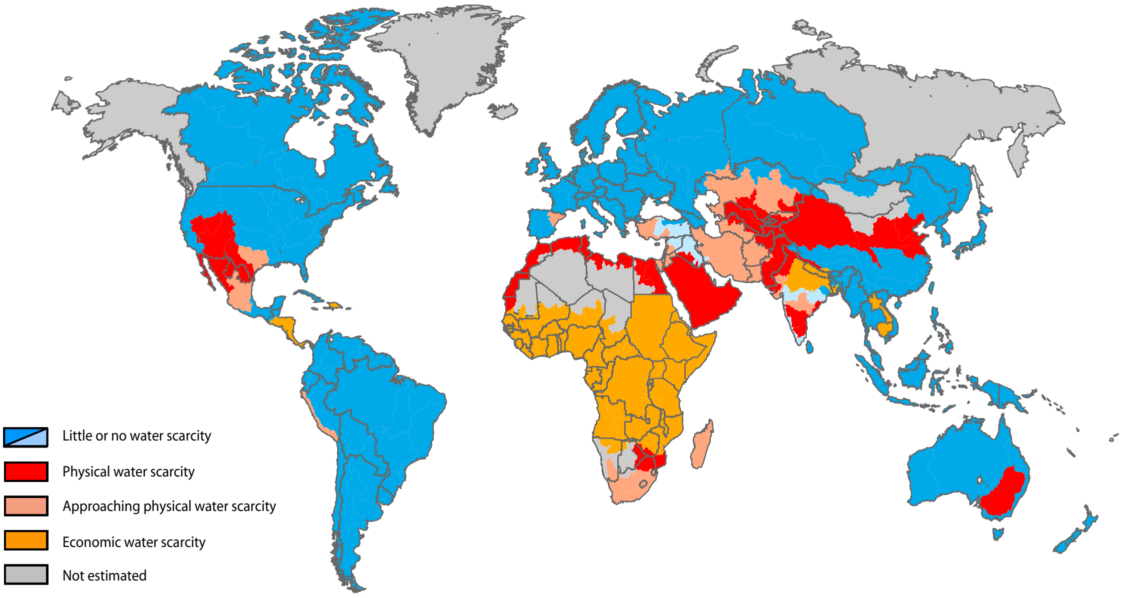
### Physical scarcity

Physical scarcity occurs when available resources are insufficient to meet all demands, including minimum environmental flow requirements. Arid regions are most often associated with physical water scarcity. But an emerging alarming trend is an artificially created scarcity, even in situation where water is apparently abundant. It is due to overdevelopment of hydraulic infrastructure, most often for irrigation. Water resources are overcommitted to various users, and there simply is not enough water to meet human demands and meet environmental flow needs.

Symptoms of physical water scarcity include severe environmental degradation including river desiccation and pollution, declining groundwater, problems of water allocation where some groups win at the expense of others. Around 900 million people live in river basins where the physical scarcity of water is absolute (the basins have closed). And another 700 million live where the limit to water resources is fast approaching (closing basins).

Several factors drive the closing of river basins. Water rights are unclear. A supply-driven logic assumes that more water is good for development. Misdirected incentives push politicians, state agencies and private companies to implement capital-intensive projects. Even an altruistic intent to invest in water for poverty alleviation at the national level can lead to a river basin's closing. The overriding political nature of water decisions takes precedence over social and hydrologic feasibility of projects.

**Map 2. Areas of physical and economic water scarcity**




**Red:** Physical Water Scarcity. More than 75% of the river flows are allocated to agriculture, industries or domestic purposes (accounting for recycling of return flows). This definition of scarcity—relating water availability to water demand—implies that dry areas are not necessarily water-scarce. For example, Mauritania is dry but not physically water-scarce because demand is low.

**Light Red:** More than 60% of river flows are allocated. These basins will experience physical water scarcity in the near future.

**Orange:** Economic Water Scarcity. Water resources are abundant relative to water use, with less than 25% of water from rivers withdrawn for human purposes, but malnutrition exists. These areas could benefit by development of additional blue and green water, but human and financial capacity are limiting.

**Blue:** Abundant water resources relative to use: less than 25% of water from rivers is withdrawn for human purposes.

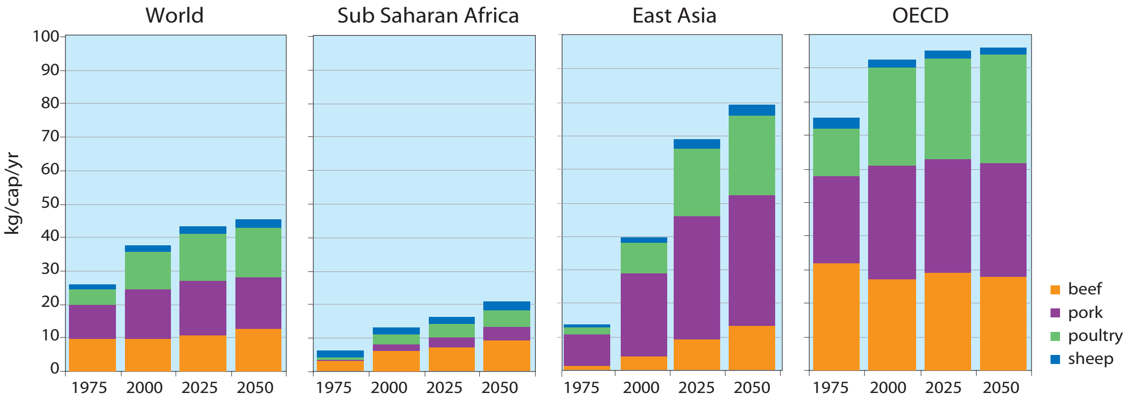
## WHAT OF THE FUTURE?

Pressure on water resources will increase with rising demands from agricultural, municipal, industrial and environmental uses. It will also increase as rising incomes spur public demand for a better environment. Because of the enormous quantities to produce food, agriculture will remain the main user of water.

### How much more food?

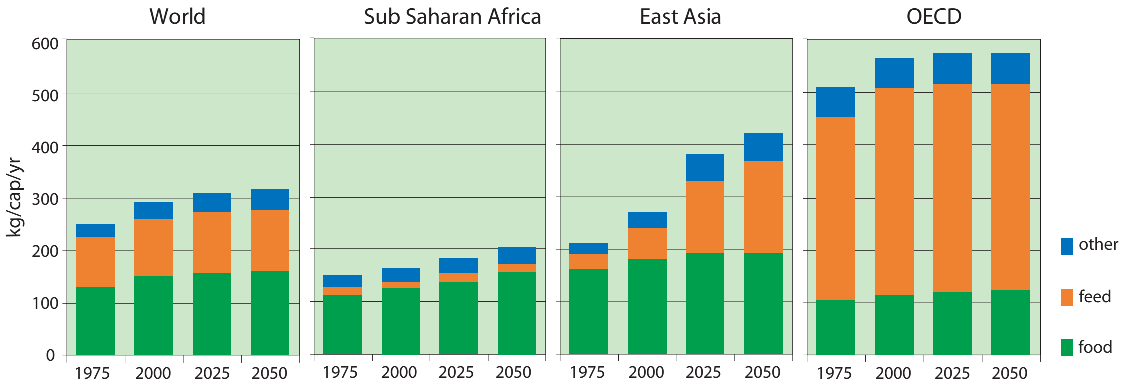
Food demand will rise dramatically, nearly doubling in the coming 50 years. The two main factors driving how much more food we will need are population growth and dietary change. With rising incomes and continuing urbanization, food habits change towards richer and more varied diets—not only to increasing consumption of staple cereals, but also to a shift in consumption patterns among cereal crops and away from cereals towards livestock and fish products and high-value crops.

**Figure 5. Meat consumption more than doubles in East Asia**




*Source:* FAOstat data and Watersim projections

**Figure 6. Feed demand drives future demand for grains**




*Source:* FAOstat data and Watersim projections

During the coming decades urbanization and economic growth will continue to drive food demand towards higher food intake per capita and richer diets, particularly in low and middle income countries.

Producing meat, milk, sugar, oils and vegetables typically requires more water than cereals, and a different style of water management. Because livestock requires more grain for feed, more than 25% of the increase in grains relates to changes in diets rather than population growth.

### How much more water?

The answer depends on where and how agricultural and animal production takes place and the improvements in water productivity—the crop production per unit of water depleted by evapotranspiration (the conversion of liquid water to vapour).

Without improvements in land and water productivity or major shifts in production patterns, the amount of evapotranspiration in 2050 will increase by 60-90% depending on population, incomes and assumptions about water requirements of livestock and fisheries. So the total amount of water evaporated in crop production will amount to 11,000–13,500 cubic kilometres, up from 7,200 cubic kilometres today. This is an average annual increase of about 5000 cubic kilometres (or 100 times the volume of water stored behind the Aswan dam). New approaches to managing water demand—including diets, trade, and water productivity improvements—will reduce the demand for future water.

**Where might this water come from?**

Meeting the water gap of up to 5,000 additional cubic kilometres of water to produce enough food by 2050 will require:

- Using more blue water in river and aquifers through intensification on existing irrigated lands or expanding to new lands using new water.
- Using more marginal quality water for agriculture, and desalinating seawater.
- Using more green water from rain and the soil by upgrading existing rainfed systems or expanding rainfed areas.
- Increasing the productivity of water to reduce the blue and green water needs in crop, aquaculture and livestock systems.
- Managing demand for agricultural water by changing diets and reducing post-harvest losses.
- Reducing water use through trade by importing from countries with higher water productivity.

**Can rainfed agriculture be upgraded to meet food demands?**

Today 55% of total gross value of our food is produced under rainfed conditions on 70% of the worlds cropland. Traditionally most investments in water management went into large scale irrigation development while neglecting rainfed areas. But upgrading rainfed areas has high potential both for food production and for poverty alleviation.
There are compelling reasons to shift our investments to improving the productivity of water and land in rainfed areas

There is a large unmet potential to increase productivity in areas where yields are low—through small-scale water harvesting and supplemental irrigation, combined with better land management.

- More rural poor depend on rainfed agriculture than on irrigated agriculture, so targeting the poor implies focusing on smallholders in rainfed areas.
- Investment costs to upgrade rainfed systems are typically lower than those of large-scale irrigation. The systems can be quickly implemented and can yield fast and high marginal returns.

- Water-driven environmental degradation can be checked because there likely is (but not necessarily) less pressure on blue water resources and less competition with wetlands.
- Large-scale irrigation development has high environmental (river and groundwater depletion and salinization) and social costs (people displaced by large reservoirs).

At the global level, the potential of rainfed agriculture is great enough to meet additional food requirements, through increased productivity. Upgrading rainfed involves adding irrigation on smaller scale.

***What if we are very successful in upgrading rainfed agriculture.***

In an optimistic scenario there is significant progress in upgrading rainfed systems and minimal increases in irrigated expansion or production gains. Reaching 80% of the maximum obtainable yield leads to a doubling of yields from 2.7 tonnes per hectare in 2000 to 4.5 in 2050 (1.0% annual growth). With no increase in irrigated production, the cropped area has to increase by only 10% to keep pace with rising demand for agricultural commodities.

But focusing only on water management in rainfed areas carries considerable risks.

- Water harvesting techniques are useful to bridge short dry spells, but longer dry spells may lead to crop failure. Because of this risk farmers are reluctant to invest in fertilizers, pesticides and labour, creating a circular pattern of risk and poverty.
- While numerous studies document the benefits of upgrading rainfed agriculture by soil and water conservation practices, water harvesting and supplemental irrigation, these tend to be isolated successes. Adoption rates have been low due to the low profitability of agriculture, the lack of markets, the relatively high labour costs and the high risks. Past efforts have not changed national yields very much
- Upgrading rainfed agriculture is not free of negative environmental consequences. It will require additional blue water (supplemental irrigation) and more green water (through better use of soil moisture). It will also require more use of agrichemicals. Very little is known of the consequences for downstream rivers and aquifers.
- Agricultural production in semi-arid areas is highly vulnerable to variable climate and to future climate change, and too much reliance on rainfall for production may reduce the ability to adapt to change.

### *But what if upgrading rainfed agriculture does not work well? – a pessimistic scenario*

If adoption rates are low and rainfed yield improvements do not materialize, cropped area expansion required to meet rising food demand will be around 60%. Globally, the land for this is available, but agriculture would then encroach on marginally suitable lands and add to environmental degradation, with more natural ecosystems converted to agriculture. If yields remain low, and land is not expanded, many more people will go hungry.

Countries without the potential to expand rainfed areas—because of a lack of suitable land or reliable rainfall—will have to import food. Global food trade will increase from 13% of total production now to 18% in 2050. There is a risk that poor countries may not be able to afford food imports (see discussion of trade below).

**Figure 7. Cropped areas under optimistic and pessimistic rainfed scenario**

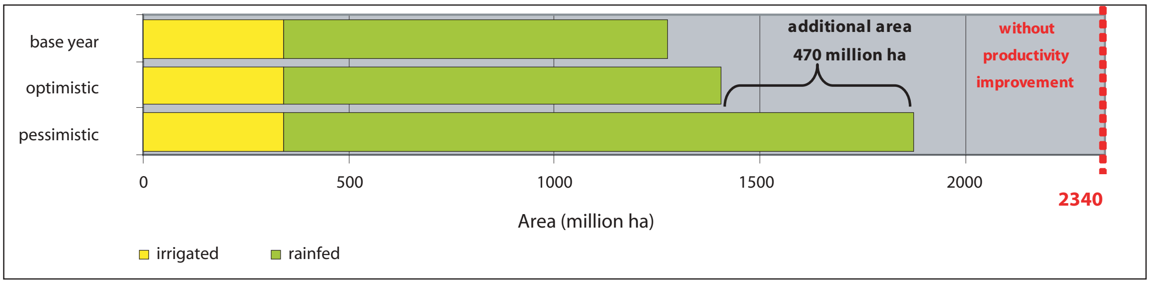
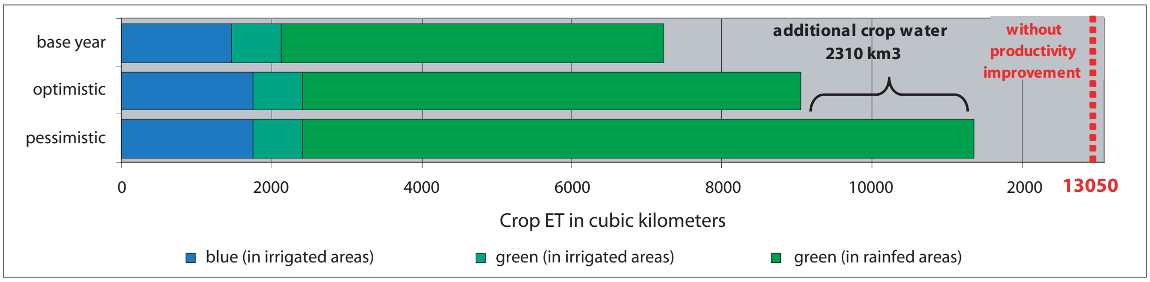



**Figure 8. Crop water depletions under optimistic and pessimistic rainfed scenario**




### What if we invest more in improving performance and expanding irrigation?

Bringing water to the crop in an effective way to increase productivity, getting a second crop a year, or a third. Indeed, to produce more food, the past 50 years saw a rapid increase in the area under irrigation, particularly in Asia's green revolution, from 94 to 280 million hectares from 1950 to today. Irrigation has been an essential ingredient in overall food production, economic growth, and poverty reduction.

In the 1980s public investments in irrigation declined in part because of low returns on investment (low food prices) and high social and environmental costs. But in recent years international donors renewed their interest in irrigation, particularly in Sub-Saharan Africa where irrigation development is limited and the potential still large.

In some areas investments in large scale irrigation make sense:

- There is substantial scope to improve the performance of many existing irrigation schemes, particularly in South Asia where yields are low, inequity is substantial and water logging and salinization problems are large.
- Providing access to water through small or large irrigation systems for productive activities has substantial potential for poverty alleviation, particularly in rural areas of Sub-Saharan Africa. Irrigation schemes can facilitate multiple uses of water, and combining agriculture with livestock, fisheries and other income-generating activities can enhance rural incomes.
- Large water storage facilities allow for stable agricultural production in areas of highly variable rainfall, minimizing the risks of crop failure and creating opportunities for higher value crops. This may become more important as the climate changes.
- Intensification through irrigation is reduces the need for added agricultural land, an environmental plus. And irrigation systems can be managed to provide other ecosystem services.

***Improving water productivity in irrigation***

What would happen in a scenario where we improve water productivity in existing irrigated areas to reach 80% of the obtainable yields? Irrigated agriculture would contribute 1420 million tonnes of grains, or 46% of world demand in 2050. Globally 60% of gross value of food production would come from irrigated areas. The highest gains in economic water productivity come from diversification and multiple uses of water, such as fisheries, livestock and small enterprise (brick making, home gardens). In India where irrigated yields are low all additional food demand could be met by improving irrigation's performance.

***Investing in expanding irrigated area instead of productivity gains***

What would happen if the irrigated area expanded by 35% and with little gains in water productivity? Irrigation would contribute 55% of total value of food supply by 2050. That expansion would require added withdrawals of water to agriculture of 45%.

The scope for enhancing productivity in irrigated areas is great in some irrigated areas, not all. India can meet all its additional food demand mainly by increasing yields. In other high-yielding areas—such as much of the developed world, the North China Plains, and Egypt—increasing water's physical productivity will be difficult. In Sub-Saharan Africa, where there is hardly any irrigation, productivity improvement would have a negligible effect on overall food supply. But doubling the irrigated area in sub-Saharan Africa would increase irrigation's contribution to food supply from 7% to 11%.

**Figure 9. Cropped area under irrigation performance improvement (optimistic) and irrigated area expansion scenarios (pessimistic)**

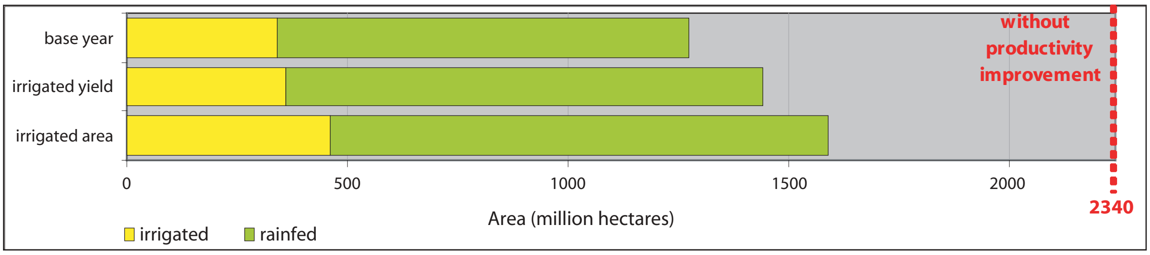
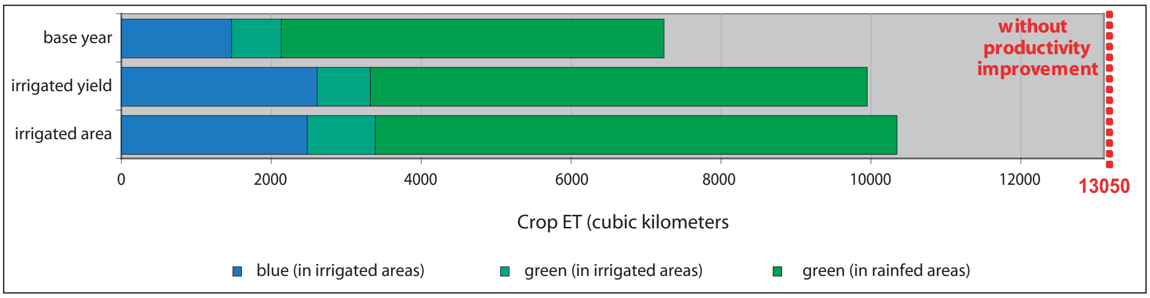



**Figure 10. Crop water depletion under optimistic and pessimistic irrigated scenario**



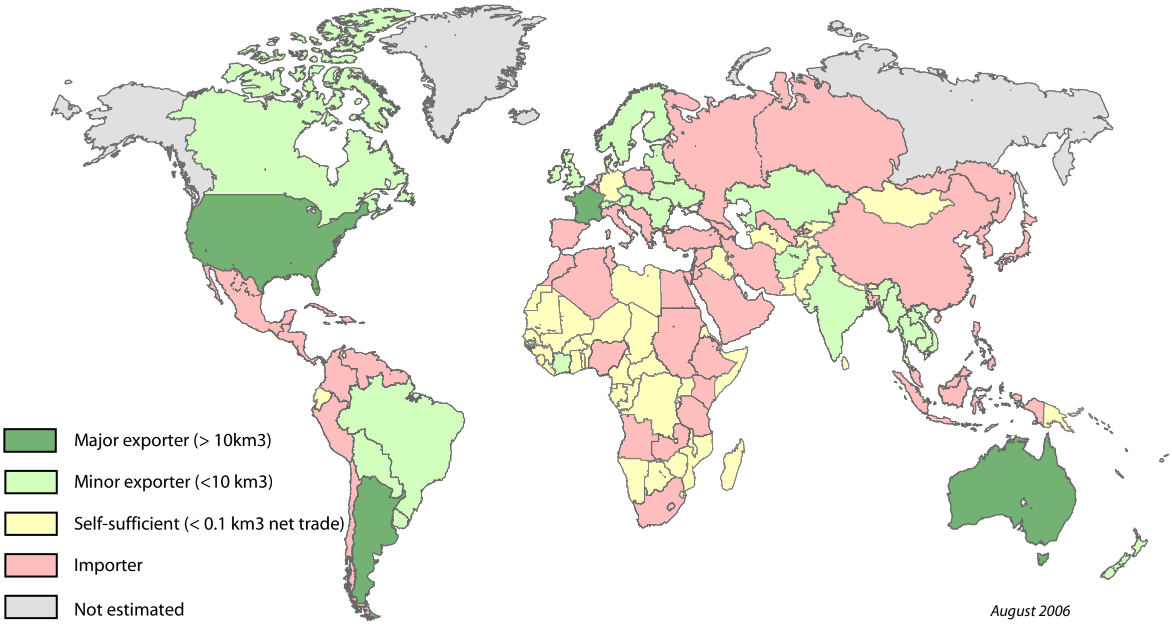

The growth of water diversions to agriculture ranges from zero in the rainfed scenarios to 37% in the irrigated area expansion scenario. Irrigation expansion leads to an increase of water depletion compared to the rainfed scenario but also 'saves' land due to higher productivity. In the irrigated area scenario total cropped area is 13% less than in the low-yield rainfed scenario. But for both water and land, improving irrigated yields is more favourable than expanding areas, while maintaining same level of agricultural output.

### *Trade to water-short areas? A matter of politics and money*

One way to alleviate water scarcity is to grow food where water is abundant, and trade it to water-short areas. Instead of using 1,000 litres of water to produce a kilogram of wheat, a country could simply import that kilogram of wheat, importing 1,000 litres of virtual water.

International food trade could thus mitigate water scarcity and reduce environmental degradation (Map 3). Instead of striving for food self-sufficiency, water-short countries would import food from water-abundant countries. Indeed, this is already happening. Egypt, a highly water-stressed country, imported 8 million tons of grains from the United States in 2000. By importing grain it 'saved' some 8.5 billion cubic meters of irrigation water—a sixth of the annual releases from the High Aswan Dam. Japan, the world's biggest grain importer, would require an additional 30 billion cubic meters of irrigation and rain water to grow the amount of food it imports.

**Map 3. Movements of virtual water**




So global food trade has the potential to meet all demands without worsening water scarcity or requiring additional irrigation infrastructure. Water-abundant Latin America, Europe, United States, Canada, Russia and Eastern Europe would step up their food production and export food to water-short countries.

While appealing from a water perspective, it is not likely from political and economic development perspective. Many countries remain wary of depending on imports to meet basic food needs, despite growing water problems. Least developed countries lacking hard currency may not be able to afford food imports and be fearful of consequences in case of devaluation or financial crisis. Many rural poor whose livelihoods depend on locally grown crops may be affected by cheap (often subsidized or dumped) imports from Europe or United States

Trade patterns will affect supply and demand of water, changing where and how food is grown. While increases in imports can reduce water-related environmental threats in one country, environmental degradation will appear elsewhere. Trade has high environmental costs in the energy and fuel transporting bulk goods around the world. There is thus a need to monitor trade implications within the water-environment-poverty nexus and take steps to reduce these negative impacts.

## CALL FOR A NEW POLICY AGENDA

It is clear that a combination of approaches will be needed in the future, and that each strategy will have inherent risks and tradeoffs. The analysis shows that:

- It is absolutely critical to focus on rainfed agriculture in poverty stricken areas for poverty reduction and increasing productivity. But this must be accompanied by increased human and institutional capacity to reduce risk.
- Enhancing the performance and productivity of existing irrigation remains important for stability of food production.
- Trade will be an important factor in the global water supply and demand equation, but cannot be relied up on address issues of environment, poverty, and individual food security. This underscores the need to focus on food production in those areas vulnerable to the uncertainty of trade.
- Whatever strategy is chosen, there will be difficult trade-offs between productivity, ecosystems, and poverty reduction.

The findings translate into a call for a new policy agenda to lay the groundwork for a new path toward the goals of food security, environmental protection and poverty reduction. The Comprehensive Assessment urges a new policy agenda to:

- Think differently about water
- Increase water's productivity: Grow more food without adding pressure on the environment
- Get water to poor people
- Consider a range of agricultural water management options
- Manage agriculture for multiple ecosystem services
- Reform public action to improve the governance of water for food and life
- Deal with trade-offs to govern water

## POLICY AGENDA #1: THINK DIFFERENTLY ABOUT WATER

Today's water management challenges—and tomorrow's—differ greatly from those of the last decades. A growing number of poor people and continued environmental degradation imply that the finite natural resources available to humans and ecosystems will not support business as usual for much longer. Thinking differently about water is a requirement if we want to reverse these trends and achieve our triple goal of food security, poverty reduction and conserving environmental integrity.

With the new thinking, investments should integrate a spectrum of activities from rainfed to irrigated agriculture, including livestock and fisheries, while considering other ecosystem services. Managing for multiple uses including ecosystem uses of water is essential to take advantage of possible synergies and to provide options for more people including landless women and men.

It is time to abandon the obsolete sectoral divide between irrigated and rainfed agriculture and to place water resource management and planning more centrally in the policy domain of agriculture at large, and not as today, as a part of water resource policy, or irrigation strategies.

The investments required today are thus much different from those in the last half century. They will have to focus on changes in human and institutional capacity, and on management and infrastructure that integrates the needs of diverse and changing demands on water resources. Table 1 describes some of the changes in thinking that will be necessary over the next half-century.

In a new agricultural water policy approach, rainfall is acknowledged as the key freshwater resource, and all water resources, green and blue, are explored for livelihood options at the appropriate scale for local communities. We need to consider the role of marginal-quality water in improving livelihoods. Rather than thinking of the water flowing out of cities as waste, it needs to be seen as the resource that it represents for many poor, urban or peri-urban farmers. We need to recognise the importance of preserving the natural resource base upon which agricultural productivity rests, and think about agriculture as an ecosystem. We also need to be cautious on the way we use available resources; aquifers over-pumped and river basins over-developed are showing their limits and presenting a different set of problems.

There is finally a need to raise awareness of the possible future impacts of global environmental change, particularly climate change or energy costs, on agricultural and water systems; and to consider their policy and management implications.

But to support a change in thinking, investments are required particularly in building knowledge and institutional reform and development. A whole new cadre of policy makers, managers and extension services is needed, where staff is trained to understand and support producers in water management investments at the farm or community level. But investments are not enough and need to be accompanied by changes in governance, and a redefinition of the decision-making power.

**Table 1. Old thinking versus broader new thinking**

| Old thinking | New thinking |
|---|---|
| Focused attention on irrigation options | Consider options from within a broad spectrum of water management in agriculture, including rainfed as well as irrigation, and integrating fisheries and livestock. |
| Considered withdrawals from rivers and groundwater | More attention to managing rainwater, evapotranspiration (green water), and reuse. View land use decisions as water use decisions. Pay attention to interconnectedness of users through the hydrologic cycle. |
| Agricultural water management and ecosystem conservation treated as separate processes | Agriculture as an ecosystem producing multiple services, interacting with other ecosystems |
| Consider benefits and costs of food production. | Consider the role of water and food in peoples' livelihoods. |
| Attention directed mainly to crop production. | Embrace diversity, gendered roles of men and women, multiple functions, multiple goals of water in agriculture |
| Water management working in a political vacuum. | Recognize and work with the highly political nature of water |
| Sectoral perspective. Raise productivity and incomes. | Broader livelihood agenda to increase assets of the poor, provide more voice in decision making, raise incomes, reduce risk and vulnerability. |
| Make investments to meet needs of the poor | Place the means of getting out of poverty into the hands of the the poor by focusing on water as a means to raise their own food; increased participation in markets for improved incomes through diversification and local economic growth; thus creating more jobs both on and off farm |
| Expand agricultural land and increase land productivity | Intensify by increasing water and land productivity to limit additional water use and expansion onto new lands |
| The state is responsible for resource development and management | Decisions on water interventions must be more inclusive and water transparent. Civil society organizations must be involved in decision-making |

## POLICY AGENDA #2: GET WATER TO POOR PEOPLE

Lack of secure access to reliable, safe and affordable water for livelihoods contributes to keeping the 800 million rural poor in poverty. And unless action is taken, many more rural smallholder farmers, fishers, herders, and people dependent on wetlands will fall into poverty because of groundwater decline, loss of water rights and access, pollution of water, floods and drought.

Smallholder agricultural systems are an important intervention point for measures aimed at preventing or mitigating land degradation in the developing world. Smallholder farmers make up the majority of the world's rural poor, and often occupy marginal land. In many vulnerable areas, smallholder farmers are in possession of the greatest unexploited potential to directly influence land- and water-use management. It is probable that supporting the small-scale agriculture sector offers the best chance for many of the MDGs to be achieved in developing countries.

Most of the world's poor depend on farming systems and natural ecosystems that rely mainly on rainfall. In fact, most of the world's 840 million malnourished people rely directly on agriculture for their food and incomes. Add to this the fact that around 70% of the world's poor live in rural areas where non-agricultural livelihood options are limited, and it is clear that improving small-scale rainfed agriculture could slash poverty and hunger. Improving agricultural productivity in areas depending on rainfall has the highest potential to reduce poverty and hunger.

Directly targeting livelihood gains by water management approaches, holds promise. Small-scale, divisible, and affordable water technologies—treadle pumps, low-cost drip, water bags for storage, low-cost pumps, small storage tanks—hold promise for livelihoods and food security. They provide water at lower unit costs than large scale hydraulic infrastructure, are affordable even by some of the poorest members of the community, and can be implemented almost immediately, without the long delay times of larger scale projects. Through the global groundwater boom, largely driven by private investments in pumps, livelihoods of millions of farmers and pastoralists in Asia and Africa have significantly improved their livelihoods and individual food security. Such investments are critical to change farmers risk perceptions, and important in enabling farmers to integrate water management with much needed investments in new tillage practices, soil fertility and crop management, pest management, diversification and market orientation.

Secure water rights of both men and women as well as marginalised groups are essential for long-term access and stability to stimulate local investment in agriculture. Those less wealthy or powerful are vulnerable to losing access to water, especially in closing basins. Yet water access rights have proven to be very difficult to define and administer. Defining rights requires an understanding of the plurality of existing informal and formal systems, the hydrologic implications of allocation, and considerable informed negotiation making sure that all are involved.

While controversial, large scale irrigation remains significant for poverty. Improving performance of existing systems and adding new irrigation can reduce poverty by increasing farmer incomes, providing employment for the landless, reducing staple food prices, and contributing to overall economic growth by inducing secondary benefits such as the promotion of agro-industry. But irrigation development, particularly large-scale development, can fail to reach the poorest, and can even make their situation worse by displacing them and denying them access to or degrading natural resources they were dependant on. In countries like India, it is clear that irrigation development had a profound effect on poverty reduction in the past, but investments in new irrigation are unlikely to have the same poverty reducing impacts. Nevertheless, large scale irrigation especially in South Asia remains the home to large numbers of rural poor who could benefit by better service from irrigation.

Where agriculture contributes significantly to GDP and employs a large number of people, irrigation can play a unique role in ensuring pro-poor growth, generating incomes to fuel non-agricultural growth, provided of course there is enough water. It is one of the few reliable options to improve nutrition, improve livelihoods and stimulate economic development. Well targeted and appropriate scales of irrigation development are strong contenders for national and international financing in sub-Saharan Africa and emerging Asian countries, such as Laos, Cambodia and Myanmar. Learning from past experience, new designs need to be more inclusive of multiple stakeholders – including fishers and herders, build on multiple use synergies, and provide manageable infrastructure.

Promoting designs and investments in irrigation systems that allow for multiple uses of water are a good option for poverty reduction. The use of water for domestic water supply, irrigation, other farm and non-farm enterprise may have higher benefits than separate investments. Many recent studies have highlighted the significant benefits and contributions to livelihoods, especially for poor households, of these multiple uses.

Many pro-poor gains in land and water productivity (policy agenda 2) come from outside of water management – better credit and insurance; support for better farm practices; improved link to markets and support services; and improved health care reduce health risks brought about by water borne diseases. This calls for integrated approaches that look beyond the water sector.

Urbanization and the global market will increasingly dictate the choices and behaviour of farmers around the world. While irrigated grain production will remain important, a variety of shifting niche markets emerge, creating opportunities for innovative entrepreneurial farmers, where suitable infrastructures and national policies are in place.

Yet it is difficult sub-Saharan African farmers to take advantage of opportunities of the global market because the powers controlling those markets are largely in the hands of developed countries who provide high subsidies for their farmers, an area that should be addressed by the international community. Yet, agricultural development remains the single most promising engine of growth in the majority of sub-Saharan countries. Water control investments should be an important part of rural development strategies in many sub-Saharan countries, but they have to be made in connection with policies that allow farmers to better serve local or regional markets.

Complementary public investment and actions are needed in the improvement of markets access and infrastructure and in regulatory fields such as land and water tenure security, specification and registration of equitable water rights and in health-related monitoring and education. The linkage between small-holders, the private sector and governments for the provision of services (technical advisory, finance and marketing) needs to be better developed. Innovative approaches, such as the farmer to farmer training, will be needed to compensate for the reduction of public extension services.

## POLICY AGENDA #3: INCREASE WATER'S PRODUCTIVITY

Water productivity will need to be significantly increased to response to growing water scarcity, environmental degradation, and the need to produce enough for a growing population. Additional water demand will strain terrestrial and aquatic ecosystem and lead to more intense competition for water resources. Producing more food with less water reduces the need for additional water in irrigated and rainfed systems.

Agricultural water productivity relates net benefits gained through the use of water in crop, forestry, fishery, livestock and mixed agricultural systems. In its broadest sense, it reflects the objectives of producing more food, income, livelihood and ecological benefits at less social and environmental cost per unit of water in agriculture.

Physical water productivity, relates agricultural production to water use – more crop per drop. Water use is expressed either in terms of delivery to a use, or depletion by a use through evapotranspiration, pollution, or directing water to a sink where it cannot be reused. Improving physical water productivity is important to reduce future water needs in agriculture.

Economic water productivity relates the value of agricultural production to agricultural water use. A holistic assessment should account for the benefits and costs of water, including less tangible livelihood benefits, but this is rarely done. Improving economic water productivity is important for economic growth and poverty reduction.

There is ample scope for improving physical water productivity, but there are also ample misperceptions about the amount achievable and how this can be done. A common perception is that because irrigation wastes so much water, reducing this waste could relieve a lot of water stress. Many investments such as canal lining or drip irrigation have been targeted to reduce wastes, but have been problematic and misguided because the perceived wastes were in fact sources of water downstream. Reuse is prevalent, especially in physically scarce basins. Reducing deliveries can be an important strategy to limit withdrawals and improve water control, but not necessarily to free up water for more uses. A basin perspective is needed to determine the impact of interventions targeted at reducing deliveries.

The primary means of lessening future agricultural water requirements are to reduce depletion (crop evapotranspiration, flows to sinks, pollution), and at the same time increasing yield. In many areas, the scope for doing so is relatively small. High yielding areas in developed countries or areas such as the North China plains, or Egypt also exhibit high physical water productivity. Moreover, improving yield from medium to high levels, requires more evapotranspiration.

But there is remaining scope in high potential areas any many rainfed and irrigated areas of the world, especially in areas where yield is low, or where salinity is a problem (box 2). In these situations, there are many promising pathways for raising water productivity over the continuum from fully rainfed to fully irrigated farming systems, which often rely on synergistic effects of land and water management. These include: supplementary irrigation (some irrigation to supplement rainfall); soil fertility maintenance; deficit irrigation (less water than required, but at the right time); small-scale affordable management practices for storage, delivery and application; modern irrigation technologies (such as pressured systems and drip irrigation); and soil water conservation through zero or minimum tillage.

**Box 2. High priority areas for water productivity gains include:**

- Areas where poverty is high, and water productivity is presently low and could benefit the poor – much of sub-Saharan Africa and parts of South Asia and Latin America.
- Areas of physical water scarcity where there is intense competition for water such as the Indus basin or Yellow River, especially gains in economic water productivity.
- Areas with little water resource development, where high returns from a little water can make a big difference.
- Areas of water-driven ecosystem degradation such as falling groundwater tables, river desiccation.

There is tremendous scope for increasing the economic productivity of water by increasing benefits and reducing social and environmental costs. This requires understanding and interventions that include livelihood and ecological benefits and costs. Integrated and multiple use systems – where water serves crops, fish, domestic purposes – can increase the value derived per unit of water. Gains in crop production have often come, for instance, at the expense of a loss in fisheries. Values generated by fisheries, including ecosystem sustenance values are routinely underestimated. Understanding values helps us to understand where there are win-win situations, and many of the important tradeoffs that will have to be made. But these values are poorly understood, and rarely enter into decision making processes.

Increasing water productivity, especially economic water productivity can be important for poverty reduction through two pathways. First, targeted interventions will enable the poor or marginalised – to gain access to water, or to more productively use water for nutrition and income generation. Second, across-the-board increases in water productivity may benefit the poor through the so-called multiplier effects on food security, employment and income. But steps must be taken to ensure that these gains reach the poor, especially rural women, and are not captured by wealthier or more powerful users only. Required are inclusive negotiation processes where there is a chance for all of these voices to be heard.

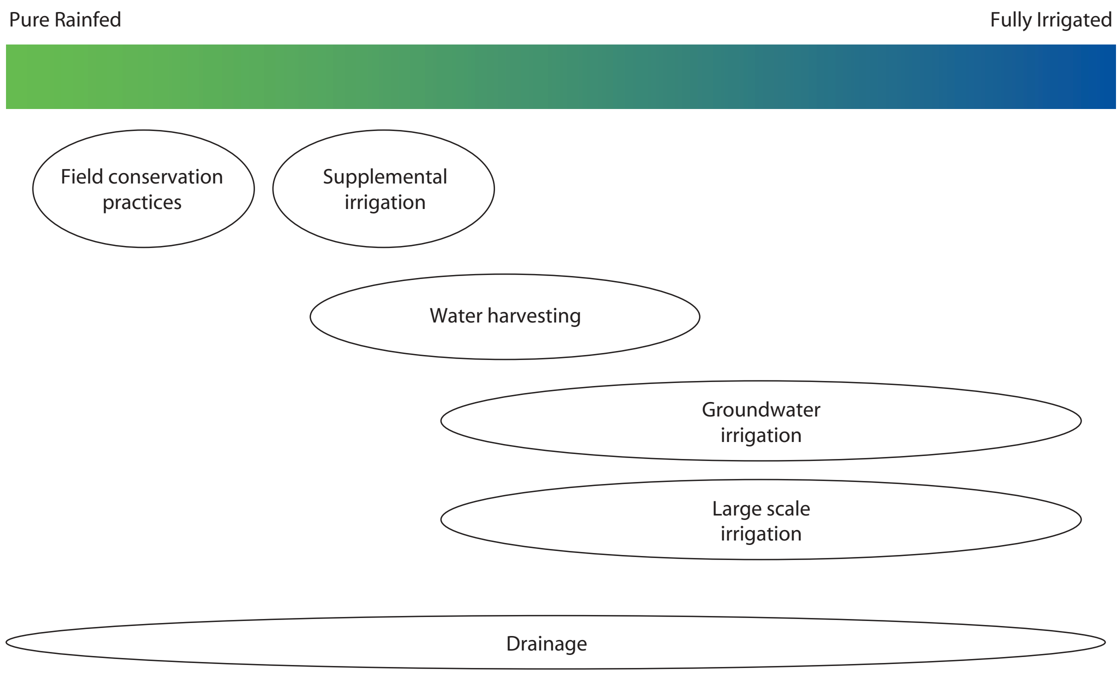
Achieving water productivity gains requires an enabling policy and institutional environment that aligns incentives of various users to encourage uptake and at the same time account for tradeoffs. In spite of existing technologies and management practices, achieving net gains in water productivity is difficult to realize for numerous reasons. The price of most agricultural produce is low, and the risks for farmers are high; productivity gains tend to reduce market prices when more produce becomes available; gains achieved by one group are often at the expense of another (crop farmers taking water out of fisheries); existing incentive systems do not support the adoption and uptake of existing technologies (who pays for water saving practices that ultimately benefit city users); the incentives of producers (more water for more income) are often much different than the incentives of broader society (less water for agriculture); gains are often captured by more powerful users, and the poor are left behind (those that can afford drip irrigation tend to do more). Many of the incentives will come from outside of the water sector and address issues of vulnerability and risk, markets and profitability of the agriculture enterprise. Research should explore ways to limit the magnitude of the trade-offs, while inclusive processes of interest groups should balance the way in which these trade-offs are dealt with.

## POLICY AGENDA ITEM #4: CONSIDER A CONTINUUM OF OPTIONS FOR AGRICULTURAL WATER MANAGEMENT

Managing water for agriculture covers a range of situations, from fully irrigated to farms dependent entirely on rain, supporting livestock, forestry and fisheries, and interacting with important ecosystems (figure 11). The continuum of water management practices starts with fields or grazing land dependent entirely green water from rain. On-farm conservation practices focus on storing water in the soil. In moving along the continuum, more blue water from surface or groundwater is added to enhance crop production. This additional blue water provides opportunities for multiple uses, including aquaculture and livestock watering within the production system.

An important dimension is the divisibility of water management technology. Some blue-water-dependent systems serve many people, often requiring public funding. Others are individually managed, such as small groundwater wells and pumps, and can be funded by individuals or communities.

**Figure 11. Agricultural Water Management: A Continuum of Practices**



Upgrading rainfed systems refers to introducing more conservation practices, or adding blue water, typically in small systems. In contrast, large-scale irrigation requires significant amounts of additional water and large scale storage and distribution systems. Many exciting options lie in the middle of the continuum – adding more blue water, or better managing of rain in large-scale irrigation.

### Upgrade rainfed systems

Better rainwater management is the key to helping the greatest number of poor people—because most of the world's poor depend on farming systems and natural ecosystems that rely mainly on rainfall. They rely on rainfed farming for food—but variable rainfall, dry spells and droughts make rainfed farming a risky business.

Improving the availability of water is the first step in raising farm productivity, for three main reasons.

- It cuts the yield losses from dry spells—which can claim one of every five harvests in Sub-Saharan Africa. This is a main reason behind the green revolution in Asia in the 1970s.
- It gives farmers the 'security' they need to risk investing in other inputs like fertilizers and high-yielding varieties. Farmers dare not risk the little they have buying inputs for a crop that may fail for lack of water.
- It allows farmers to grow higher value crops, such as vegetables or fruits, for market. These are more sensitive to water stress and need costlier inputs. Farmers can then move away from low-value staple food crops and earn cash incomes—valuable rungs on the ladder out of poverty.

**Box 3. Key steps for tapping rainwater's potential to boost yields and incomes**

1. **Make more rainwater available to crops when it is most needed**—by capturing more rainfall, storing it for use when needed-adding irrigation to rainfed systems, using it more efficiently, and cutting the amount that evaporates unused. Water harvesting, supplemental irrigation, conservation agriculture/tillage and small-scale technologies (treadle pumps and simple drip-irrigation kits) are all proven options.
2. **Build capacity**—efforts should ensure that extension services can get rainwater-exploitation techniques out to farmers and work with them to adapt/innovate for their specific context, and that water planners and policy-makers can develop and apply rainwater management strategies.
3. **Expand water and agricultural policies and institutions**—rainwater management needs to be specifically included in management plans for upper catchments and on farms to ensure the productive use of rain.

### Reinvent large-scale irrigation

A major task is to adapt yesterday's irrigation systems to tomorrow's needs. The needed productivity gains are possible across the full spectrum of existing irrigated agriculture and will increasingly be driven by the market and incentives that lead to profitable farm incomes. Large scale surface irrigation systems will incorporate better information and water control to be more responsive to the needs of the many users of irrigation water including crop farmers, livestock keepers, fishers and those who use water for small industry or domestic use. Irrigation management must also increase the predictability of water supply in a context of scarcity. More finance will be required for well conceived improvements in water control and delivery, automation and measurement, and for better training and professional development of staff.

Countries facing a legacy of ageing irrigation infrastructure will need to invest much more in technical and managerial upgrading—and less in new development. Investments in drainage are likely to continue at fairly modest levels, although regional waterlogging and salinization problems from past development will continue to require remediation. There will thus be considerable tension between these financial needs and a government's willingness and ability to finance them.

### Manage groundwater sustainably

As a result of a global 'groundwater boom', millions of farmers and pastoralists in Asia and Africa have significantly improved their livelihoods and household food security. But aquifer depletion and groundwater pollution—a direct result of this intensive use—imply that existing trends in groundwater use will not be sustained unless accompanied by far more intensive regimes of resource management.

The groundwater boom has been driven by 'supply-push' factors—such as easy availability of inexpensive pumps and drilling technologies, government subsidies—and by 'demand pull' factors arising from groundwater's capacity to provide flexible, on-demand irrigation to support vibrant, wealth-creating agriculture in all climatic zones, and from the growing need to provide food for urban populations. By far the most powerful 'pull', however, has been experienced in South Asia and North China, where the 'land-augmenting impact' of groundwater has proved irresistible.

In the face of growing concern about overpumping and pollution, groundwater use in agriculture shows no sign of ebbing. Our surmise is that it will continue to rise in many parts of the developing world. Participatory approaches to sustainable groundwater management will need to combine supply-side measures (artificial recharge, aquifer recovery, inter-basin transfer of water) with demand-side measures (groundwater pricing, legal and regulatory control, water rights and withdrawal permits, promotion of water-saving crops and technologies.)

Not all these measures are immediately suited to developing countries if approached from a formal water management perspective. Supply-side measures have proved easier to implement than demand-side measures—even in technologically advanced countries. In the absence of supply augmentation, the only way to relax aquifer systems to an acceptable degree may be to reduce irrigated areas, improve farming practices and switch to water-saving crops. But this may be difficult to implement in socio-economic and political terms in developing countries.

### Use marginal quality water as a resource

Blue water of marginal quality is an increasingly important source of water. Millions of small-scale farmers in urban and periurban areas of developing countries irrigate with wastewater from residential, commercial and industrial sources, in many areas not treated before use. Millions of other farmers in deltaic areas and tailend sections of large-scale irrigation schemes irrigate with a blend of canal water, saline drainage water, and wastewater. Many of them cannot control the volume or quality of water they receive within a week, month or season.

Additional farmers in developing and industrial countries irrigate with saline drainage water or saline/sodic groundwater, either exclusively or in conjunction with higher quality surface water. Soil salinization and waterlogging impair the productivity of millions of hectares of agricultural land. Irrigating successfully with saline/sodic water requires careful management to prevent near-term reductions in crop yield and long-term reductions in productivity.

Where public budgets are inadequate to treat wastewater, farmers provide a service by collecting and using untreated wastewater for irrigation. The revenue they generate enables them to support their families, perhaps enhancing local and regional economic activity. In addition, city residents have access to a local supply of fruits and vegetables that might not be available if farmers were unable to irrigate with wastewater.

The downside of the increasing supply is increasing the aggregate risk to farmers, consumers and the environment. The long-term health effects of the increasing use of untreated wastewater might eventually weigh on public budgets, either directly in the form of public expenditures to protect health and welfare, or indirectly in declining productivity of lands irrigated perpetually with low-quality wastewater.

## POLICY AGENDA ITEM #5: MANAGING AGRICULTURE FOR MULTIPLE ECOSYSTEM SERVICES

Historically, agriculture has been a major driver of ecosystem loss and degradation. In the past, people have managed agro-ecosystems simply to optimize crop production—without considering the larger landscape. Seeing the big picture is vital if managers are to avoid creating one problem when solving another. Up to 50% of the Earth’s agricultural land, and half the river systems, are now affected by some degree of degradation. Agricultural water management can negatively impact ecosystems by:

- River depletion and consequent degradation of downstream aquatic ecosystems with devastating effects on groundwater and fisheries.
- Drainage of wetlands and run-off or discharge of wastewater to surface and groundwater-dependent ecosystems.
- Groundwater depletion by over-exploitation for irrigation, causing damage to groundwater-dependent ecosystems.
- Pollution from overuse of nutrients and agro-chemicals with consequences both for terrestrial and aquatic ecosystems and for human health because of water pollution.

**Box 3. The costs of going too far: the Aral Sea in Central Asia**

The Aral Sea is a dramatic example of consequences from a narrow focus on crop production. Due to water diversion for large-scale irrigation the Sea shrank by 75%, large areas of wetlands were lost, and fisheries collapsed with a loss of 60,000 jobs. The effects are on-going, huge quantities of toxic wind-blown dust containing agro-chemicals are now killing crops and causing serious lung disease in the region. Restoration is underway, but is unlikely to result in the return of the entire sea and the many services it formerly provided.

- Combined situations where river depletion exacerbates water pollution problems by decreasing possible river dilution.

Degradation of the resource base reduces the ecosystem services an area can provide and in some cases can even jeopardize food production (box 3). Degradation has particularly serious consequences for small-scale farmers in developing countries leading to low productivity, declining returns to labour, and negative human health consequences including rising malnutrition, and the increasing pollution of drinking water.

Increased food production has come at the expense of biodiversity and other regulating, supporting, provisioning and cultural ecosystem services, often quite important to poor peoples' livelihoods. Sometimes food provisioning services are pitted against one another, for example, gains in crop production have often come at the expense of a loss in fisheries. Investments in water, crop intensification, fishery and livestock development often failed to achieve their maximum return because of the failure to integrate different sectors and understand their ecological dependence.

Needs for more water and land for more agriculture in the future will place increasing stress on ecosystems. Clearly some of the past problems can be avoided in the future, and serious rehabilitation efforts are required, but there will be some difficult choices that have to be made entailing tradeoffs between users. These tradeoffs mean conflict, negotiation, and shifts in water governance.

Many of these negative impacts are avoidable. Agricultural systems can generate valuable 'ecosystem services' besides food, fibre and fuel. These include nutrient-cycling and soil-formation processes, as well as flood, erosion and water-quality control, and cultural and aesthetic benefits. Production of food does not have to be at the total expense of services provided by wetland ecosystems, rivers and other non-agricultural systems; it can be better managed to support a range of ecosystem services.

These services and these interactions generally go unrecognized. Yet in many cases they could be optimized to provide more productive and sustainable agro-ecosystems. In the same way, values generated by fisheries are routinely underestimated. Better understanding and communication of those values would help in identifying potential win-win situations and what many of the important trade-offs will be.

To avoid agriculture further damaging the environment, a new integrated and adaptive approach is needed to manage the water used by agro-ecosystems. This should explicitly recognize and deal with tradeoffs, and maximize the number of ecosystem services that farming landscapes supply (Box 4). Enhancing services provided by agro-ecosystems can help to replace services that were lost because of conversion to agriculture, and enhance resilience thus reducing agriculture's vulnerability to droughts and other extreme events.

**Box 4. Some ecosystem services provided by multi-functional rice-fields**

| | |
|---|---|
| **Provisioning:** | - rice |
| | - fish and ducks (sometimes frogs and edible snails) |
| **Regulating:** | - large water storage capacity, which also helps to reduce flooding |
| | - sediment and nutrient trapping (better water quality) |
| | - soil erosion and landslide prevention |
| | - greater groundwater recharge (increasing water availability to poor farmers who tap shallow aquifers) |
| **Supporting:** | - high biodiversity, due to complex mosaic of flooded fields, canals and dry land |
| **Cultural:** | - social cohesion |
| | - traditional festivals and religious rites |
| | - scenic beauty |

But there is a lack of incentives because many of these benefits do not directly reward producers. Innovative schemes that provide compensation for these services are required; compensating upstream farmers for releasing water to specifically support fisheries downstream is one example. Paying villagers to maintain mangroves for coastal protection or maintenance of fish nurseries instead of converting them to shrimp ponds is another..

To address land degradation from the individual farm up to the landscape level, integrated preventative and remedial measures are necessary that focus on resource-conserving farming strategies, and on sustainable soil and water productivity. Eco-agricultural approaches can create better synergies between agricultural production, water and wild biodiversity, benefiting the ecosystem as a whole. Integrated land and water management drawing on such strategies reveal carbon sequestration and clean water benefits.

Better water and land management will require efforts to make people more aware of the benefits that ecosystem services provide (Box 3) and informed consideration of the trade-offs between producing food, sustaining other ecosystem services and the resource base. At the same time managers need to manage with uncertainty about ecosystem change – we do not know everything, but we do know that in places we have pushed things too far and they can not bounce back as some change is irreversible.

**Box 5. What is needed to shift to managing for more ecosystem services?**

- **Raised awareness** of the role and value of ecosystem services—through education, information dissemination, and dialog between stakeholders, sectors and disciplines.
- **Greater scientific understanding** of ecosystem services.
- **More tools for assessing trade-offs**—to help us decide which ecosystem services in a particular area most benefit society. Existing tools range from cost–benefit analyses and risk and vulnerability assessments, to 'desktop' models for estimating the water flows required by wetlands.
- **Better inventory, assessment and monitoring,** especially of factors related to ecosystem resilience and thresholds that, once crossed, mean a system can no longer provide a particular service.
- **New 'paths' for integrated, inclusive decision-making**—currently a complex web of policies and organizations governs environmental management.

## POLICY AGENDA ITEM #6: REFORM THE STATE TO IMPROVE THE GOVERNANCE OF WATER

The state will play a critical role in water resource development and management through its policies, resource allocations, regulation and financing. Ironically, the state is often the institution most needing reform to address new challenges, but it must also drive broader institutional and policy reforms.

The roles of public bodies in charge of water management and agricultural development have changed in the last 50 years. There is a continuing decentralisation of management roles and in particular a trend to devolve management responsibility and shed the costs of management to users and farmers. This will intensify.

There is also a growing need to get to an integrative management at the appropriate scale of water systems (watershed, larger basin, aquifer). This implies managing both water and land, managing of multiple water users and needs, and managing agro-ecosystems for food security, poverty reduction and environment sustainability.

### Rethinking public action

The state plays multiple roles, intervenes at multiple levels and interacts with multiple stakeholders. But public bodies are not well prepared for some of these new functions. There is a need to address these new challenges through broader institutional and policy reforms.

There will be many possible outcomes ranging—from full farmer ownership and operation, to contracted professional management, to joint management between government and farmers. The government's withdrawal from direct managerial functions will need to be offset by regulatory capacities and mechanisms to oversee and regulate service provision in order to guarantee equitable water allocation while ensuring efficiency in the use of water. Bulk water supply infrastructure, due to its multiple functions and strategic value, will remain a state concern.

What public action is needed to improve governance

- *Recognize the inherently political nature of institutional reform processes.* Generalization and advocacy of single-dimensional solutions are impractical. Required instead is insightful analysis of what is possible, how to create coalitions, and who can be effective champions. One option does not fit all.
- *See reforms as sociocultural processes that do not start from a blank slate.* The processes are embedded in a socio-technical context with a history, a culture, an environment and vested interests. This context shapes the scope for future change. It is also in a state of flux—which can create opportunities for negotiating reforms but make outcomes inherently unpredictable.
- *Adapt today's governance structure to tomorrow's needs*. The state will retain its role as the main driver of reform for the foreseeable future, but it is also the institution most in need of reform. The state must take responsibility for ensuring greater equity in access to water resources and using water development and management to reduce poverty. Protecting essential ecosystem services is also vital for many reasons, including their importance to poor people's livelihoods.
- *Share knowledge and information equitably*. More data need to be generated, turned into reliable information and (most critical but also most problematic) shared widely with stakeholders to empower them through better awareness and understanding—that is, through knowledge. New skills and capacities in water management institutions are critically important—at a time when various forces are weakening government capacities to attract and hold people with this expertise.
- *Enable social action and public debate.* The state cannot make all these changes alone. Public debate based on shared trusted information creates a higher degree of legitimacy and understanding of the reasons for change and increases the likelihood of implementation. This process of knowledge sharing and debate creates opportunities to include and empower poor stakeholders—those with potentially the most to gain (or lose).

What would help achieve this public action? First is research to support reform processes and reduce the high level of uncertainty of reforms as socio-political processes.

Negotiating reforms is the 'art of the possible,' but applied professional research informing the art will make successful outcomes more likely. Second is paying more attention to finding ways to institutionalize social equity, poverty reduction and ecosystem sustainability. Third is capacity building and empowerment.

## POLICY AGENDA 7: DEALING WITH TRADE-OFFS AND DIFFICULT CHOICES

In water management, the only certainty is change. Even with the best science, there will always be a high level of uncertainty about external drivers and about the impacts of various decisions. Difficult choices are required, and there is high uncertainty. Water management institutions require learning capacity to identify danger signs, and be flexible enough to make changes to policy possible when better understanding is available. Informed multi-stakeholder negotiations are required to strike trade-offs, and innovative means to ensure the application of decisions are required.

While the role of the state in driving reforms is critical, it cannot make changes alone; writing new laws or passing administrative orders alone achieve little. A process of public debate based on shared trusted information creates knowledge, a higher degree of legitimacy and understanding of the reasons for change, and increases the likelihood of implementation. This process of knowledge sharing and debate creates opportunities to include and empower poor stakeholders—those with potentially the most to gain (or lose), including those who often go unrecognized – the landless, fishers, pastoralists, and those dependent on wetland and forest ecosystem services.

However good governance is rarely triggered by well-intentioned policy documents or participatory rhetoric alone. The Assessment finds that more balanced decision-making outcomes are generally reached when and where there is a mix of political space allowed by the state and active organization of the civil society to defend particular causes or population groups.

Integrated Water Resources Management aims at achieving goals of economic efficiency, equity, and environmental sustainability but these goals can rarely be fulfilled all together. Although better integration of objectives is possible in general one will be achieved to the detriment of the other. More efficient economic activities often favors capital-intensive ventures and investors rather than smallholder farmers. Environmental conservation or defining environmental flows generally means taking water away from existing productive uses. In other words tradeoffs have to be made and where the balancing points lies depends on who is convened at the decision-making table; what interests, values and worldviews are considered; and how existing power relations play out or are being influenced. Problems of infrastructure planning or water allocation at basin levels, for example, are best addressed through informed and inclusive processes where parties may learn from each other, recognize other parties' interests, and possibly adapt their stance.

In many river basins use of water for human purposes through investments in water infrastructure for urban, industrial, and agricultural growth is approaching or exceeding the amount of renewable water available, and basins are said to be closed. Such overcommitment of water resources is caused by a disregard for environmental water requirements, incomplete hydrological knowledge, fuzzy water rights, and politically motivated projects with weak economic rationale. With basin closure the interconnectedness of the water cycle, aquatic ecosystems, and water users increases greatly. Local interventions such as tapping more groundwater, lining canals, or using micro-irrigation often have third-party impacts and unexpected consequences elsewhere in the basin.

In closing basins users and managers tend to adapt to scarcity, conserve water, and resort to multiple sources, while local "losses" are reused elsewhere in the basin. Thus the scope for using water more efficiently at the basin level is frequently much smaller than assumed. Based on a solid hydrological analysis, planners need to gauge whether there is scope for saving water or simply for redistributing it and to make sure that possible third-party impacts are avoided or compensated for.

Anticipating impacts and deciding how benefits and costs will be distributed cannot be achieved by line agencies or by one river basin organization alone. Instead political processes which attempt to reconcile interests can negotiate more balanced outcomes. In river basins such issues are better resolved through polycentric types of governance where a basin agency focuses on co-ordination between government agencies and stakeholder representative, on providing technical and hydrologic information, and on application of the law. Because problems are complex and stakeholder participation often not part of existing bureaucratic cultures, such governance will only be effective when a degree of democratization allows sufficient political space for such participation to occur.

Comprehensive assessment
of water management in agriculture

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