Water, Food and Environment:
A Development Dilemma

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KEYNOTE ADDRESS

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As much as seventy times more water is needed to grow food than for domestic use. Severely water-scarce countries such as Egypt do not have enough water to grow their own food and need to import food from elsewhere. Countries like the USA, Australia, China, India, Mexico and Turkey have made massive investments to build dams and develop irrigation systems. As a direct consequence, the famines predicted for India have not occurred and world food prices are lower than ever. But rivers are drying up, groundwater levels are falling dramatically, and water pollution is rampant near most Asian cities. All water that falls as rain serves a purpose in nature. If farmers don't have an incentive to conserve water, over-use is the likely consequence and nature pays the price. Good government policy helps water move from lower to higher-value uses. Where water gets scarcer, agricultural use that generate only cents of value per cubic metre needs to shift to higher-value uses, or to return the water to nature. Research can help determine the value of water in alternative uses, even for nature. Agricultural research also works to increase the value of water in agriculture. A combination of smart engineering and agronomy can drive the water needed to produce a kilogram of rice down from 2000 to as little as 500 litres. To keep agriculture competitive and sustainable, a 50% increase in the value of water in agriculture will be necessary — and is feasible — worldwide over the next two decades.

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Introduction

The world water crisis has already arrived for about a third of the world's population. That is one of the key conclusions of a major assessment of water management in agriculture that is about to be released (CA 2007). The same scientists at the International Water Management Institute carried out a similar analysis, published in 2000, that predicted that a third of the world population would face water scarcity by 2025. In other words, the situation is worse than expected only recently. And as the reports on climate change get more and more serious, a business-as-usual scenario is likely to result in even more grim outcomes. Droughts such as the one Australia is experiencing today are likely to become more frequent. And if the latest trend in the energy sector — to grow more bio-fuels — really catches on, that will increase the demand for additional water even further.

Does that mean that there is not enough water to go round? That we are running out of water to satisfy the basic human needs of drinking, washing, bathing, producing food, cooling industry and maintaining ecosystem services? No, it does not. The water scarcity we experience today is a result of the water development and management choices we made yesterday. There are options to manage water differently, to shift use in some places from low-value outputs to high-value outputs, to shift some uses to the places where water is available, and to use water more efficiently. The demand for water will also need to be managed: users need to have incentives to conserve — which includes paying a price for — water that reflects its scarcity and encourages conservation.

This paper lays out what the authors see as the main water dilemma: how to balance the needs of agriculture and nature for water. How to produce economic returns for the rural poor in Africa as well as Australia's agro-industry, and how to do that in a way that maintains healthy wetlands in Africa and a Living Murray in Australia. The paper then lays out the key options for solving the world water crisis, and recommends actions. The primary focus of this paper is on the needs of the poor in the developing world, but it discusses the links and parallels with Australia.

The dilemma

During the 20th century the world population tripled and water use grew six-fold. The bulk of the increased water use went to irrigated agriculture. Countries like the USA, Australia, China, India, Mexico and Turkey have made massive investments to build dams and develop irrigation systems. As a direct consequence, the famines predicted for India have not occurred and world food prices are now lower than ever. Around the turn of the century India had managed to overcome a predicted massive food shortage and was more than food-self-sufficient in some years. Countries like Thailand and Vietnam have become major agricultural exporters.

But rivers are drying up, groundwater levels are falling dramatically and water pollution is rampant near most Asian cities. All water that falls as rain serves a purpose in nature. Ecosystems need enough water to provide ecosystem services, necessary for our well-being and survival. The Millennium Ecosystem Assessment (MEA 2005) concluded that agriculture is a key driver of environmental degradation. Agriculture is also by far the largest human use of water and drives water scarcity.

Still, for many of 800 million dollar-poor people who live in rural areas, particularly in Sub-Saharan Africa, agriculture is still the primary ticket out of poverty — and increased access to water for agriculture is very high on their priority list. Most hungry and poor people live where water challenges pose a constraint to food production — the semi-arid and arid tropics; despite global food self-sufficiency, there are still many malnourished people in the world.

The Global Water Partnership concluded in their document for the 2nd World Water Forum that:

> On the one hand, the fundamental fear of food shortages encourages ever greater use of water resources for agriculture. On the other, there is a need to divert water from irrigated food production to other users and to protect the resource and the ecosystem. Many believe this conflict is one of the most critical problems to be tackled in the early 21st century (GWP 2000, p. 58).

That, then, is the water, food, environment dilemma: how can we, first, find the water necessary for domestic use and cities, and then have enough water left over to produce food and help poor people escape from poverty, without endangering the ecosystem services that will be crucial to the quality of life for our children?

How much water do people use?

To understand the key dimensions of this dilemma better, it is useful to understand how much agriculture dwarfs domestic water use and, in most of the world, industry (see Table 1). While obviously the water people need for drinking is crucial to them, it is only a very small fraction, about one-tenth of one per cent, of the water people require to produce their food.

Clearly, how much water people use depends on their diets (see Table 2). As a rule of thumb, however, it takes about one litre of evapo-transpiration (i.e. water that is either transpired by a plant or evaporated from the soil) to produce each calorie.

Table 1. Water for life, water for food

Water use	Volume of water (litres)
Daily drinking water / person	2–5
Daily household use	20–400
Cereal production: 1 kg of grain	500–2000, as evapotranspiration (ET)
Vegetarian diet / day	2500 as ET
Grain-fed meat diet / day	5000 as ET

Growing food requires some 70 times more water than people use for domestic purposes.

Table 2. How much water for food?

Country	Volume / person / day (litres)	Allocation to components of diet
Thailand	2800	40% for cereals; 20% for animal products; rest for pulses, sugar, oils
Ethiopia	3000	Two-thirds for milk and beef; 15% for cereals (tef, maize)
Italy	3300	Half for ham and cheese; a third for pasta and bread

Derived from the Comprehensive Assessment (CA 2007).

Calories from animal products are much more water-intensive then calories derived from plants, but the water used to produce meat can either be soil moisture — 'green water' — on rainfed grazing land, or it can be irrigation water taken from rivers, lakes or groundwater — 'blue water' — used to grow cereals that are used as animal feed. While both need water, the green water cannot be piped into a city and therefore does not compete with domestic water supply, although it does compete with the natural ecosystem that could have used the same water instead.

As economies develop and people's incomes rise, diets tend to change as well. Simulations of the water required to grow cereals in the years 2025 and 2050 show that water to produce animal feed in East Asia dominates the increasing demand for water, due to the increased demand for meat and animal products in China (see Fig. 1).

Investments in water resources development

The massive investments in water resources development in the 20th century, mainly to build large dams and irrigation systems, have helped to increase the overall levels of production and to reduce the impact of rainfall variability on agriculture. But those investments have been very uneven (see Fig. 2).

Irrigation engineers used to think that their goal was to capture water in reservoirs before it would flow to the sea and be 'wasted'. In some parts of the world, so many dams have been built that many rivers indeed barely reach the sea anymore. People around the world discovered, however, that all rainwater serves a purpose in nature. Every drop taken has a trade-off. As long as the value of water for nature is not recognised, and water for agriculture is subsidised, the chances are that too many dams will be built.

There are, however, enormous differences in different parts of the world. While the reservoir storage capacity constructed in Australia came to about 4700 m^3 for every Australian in 2003, Ethiopians facing a similar climate and climate variability had only 38 m^3 each. So while it makes sense to debate whether too many dams have been built in Australia and North America, clearly in Sub-Saharan Africa there is great need for additional investments in water resources development.

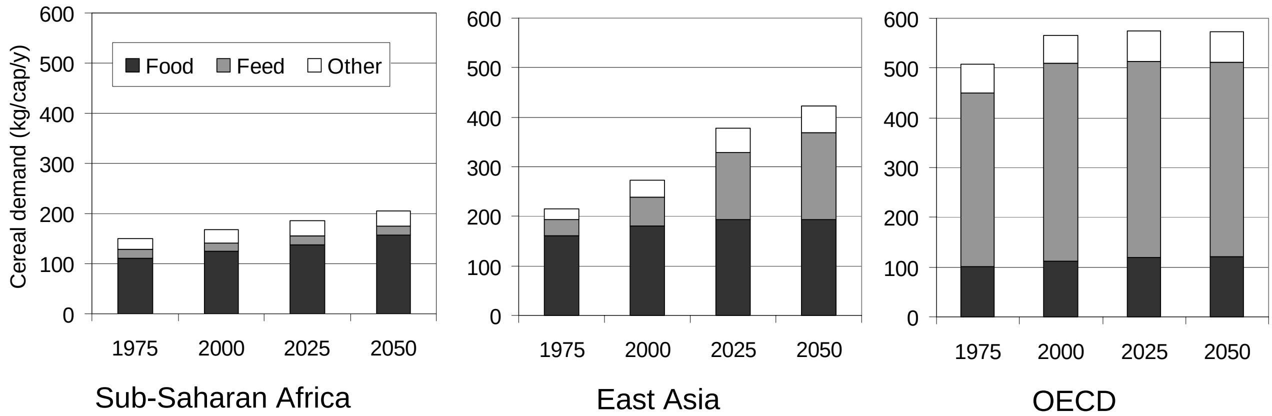


Figure 1. The future demand for cereals is dominated by animal feed (Source: CA 2007)

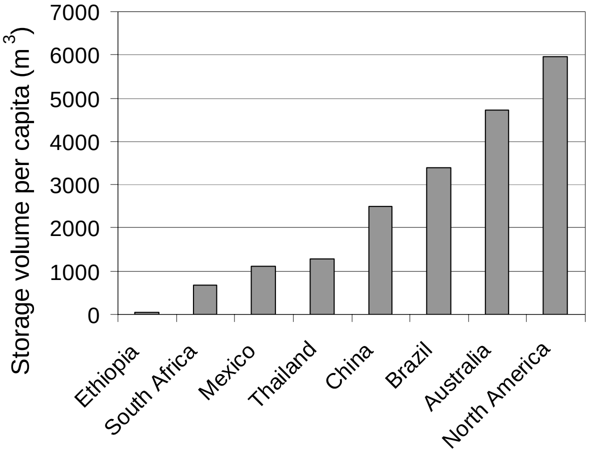


Figure 2. Water storage mitigates rainfall variability (Source: World Bank)

Water scarcity and closed basins

Worldwide, a billion people do not have access to safe and affordable drinking water. Together with lack of access to sanitation and poor hygiene, it causes the death of over two million people every year, mostly young children who die of diarrhoea. These people do not have access to safe and affordable drinking water and sanitation. But that is not, or only in exceptional cases, because there is not enough water available for domestic water supply. Poor people do not have access to safe drinking water because they are poor, not because there is not enough water. Poor people then use either unsafe, dirty water (and get sick), or they pay large amounts of money for small amounts of water from private water sellers — often at prices that are many times that of the subsidised tap water flowing into the homes of their better-off neighbours. Lack of access to water for poor people is a similar problem to poor people not having food or shelter, and water scarcity is not a significant factor. In fact, because the value of water to people for domestic use is so much higher than the value of water in agriculture, as evidenced by what people pay for water (see Table 3), it is clear that cities and industry will always out-compete agriculture for water — if given a chance.

Table 3: What people pay for water: for many poor people, drinking irrigation water can be the best option available

Source of water	Price (US$ / m^3, i.e. 1000 litres)
Designer water — Perrier	Up to 10 000
Regular bottled water	100–200
Tap water	1–2
Irrigation water	0.01–0.02

Tap water is a hundred times more expensive than irrigation water; bottled a hundred more than tap.

Farmers generally pay no more than cents per cubic metre of water, if they pay at all. The really tough water decisions are to balance water for agriculture with water for nature; to make sure that where water moves from agriculture to cities, agriculture does not in turn take yet more water from nature. Many countries are just coming to terms with the fact that free water has run out. Water is available, but at a price.

So are we running out of water to produce food? In 2000, IWMI published a study that predicted that by 2025 one third of the world population would be facing water scarcity (see Fig. 3).

IWMI's often-quoted map combined 'physical water scarcity', where there simply is not enough water to meet all demands, such as in the arid areas of the Middle East, with 'economic water scarcity', when the water is there in rivers and groundwater, but the physical infrastructure is lacking to make it

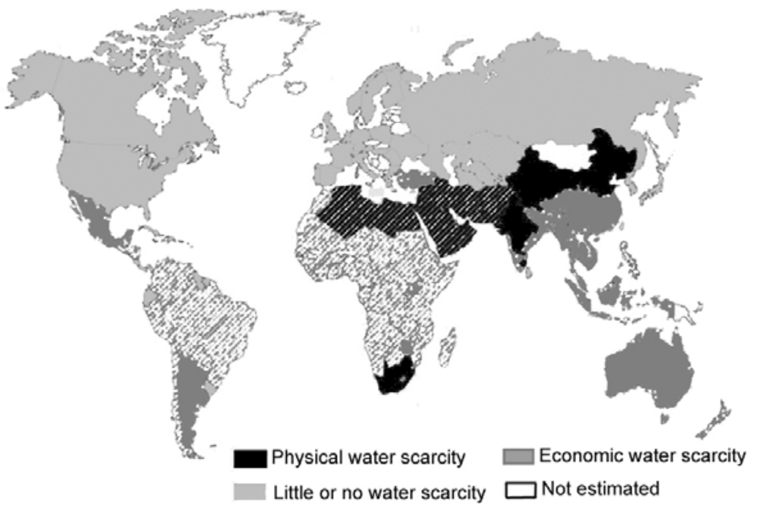


Figure 3. Projected water scarcity in 2025. IWMI water scarcity map in 2000: physical and economic water scarcity for one-third of the world population by 2025 (Source: Cosgrove and Rijsberman 2000)

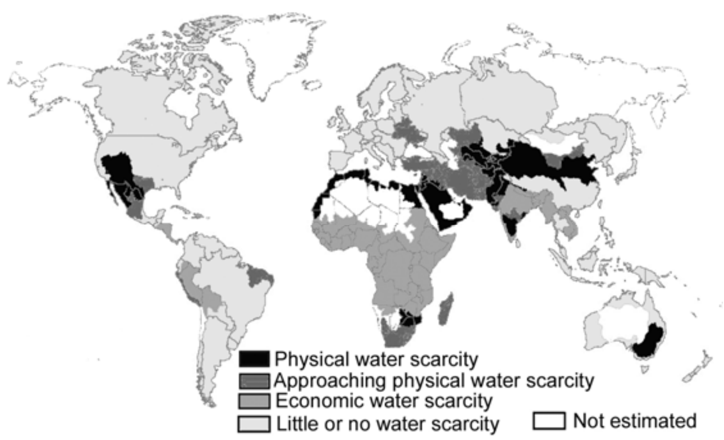


Figure 4. Water scarcity 2000. IWMI water scarcity map update in 2000: one-third of the world population already faced water scarcity in the year 2000 (Source: CA 2007)

available to people when and where they need it. A large part of the developing world is economically, rather than physically, water scarce.

In 2006, the same IWMI scientists carried out a more refined and improved analysis and produced an updated map (Fig. 4).

Rather than analysis at the country scale, as was the basis for the 2000 map, the new map analyses water scarcity at basin level. The conclusion from this new study was that one-third of the world's population was already facing water scarcity in one form or another in the year 2000, i.e. 25 years earlier than predicted before. The key conclusion is that it is possible to produce the food, but it is probable that today's food production and environmental trends, if continued, will lead to crises in many parts of the world (CA 2007).

The new map shows much better where physical water scarcity is an issue, and that includes the Murray–Darling basin in Australia, as well as the economic water scarcity that is by and large limited to Africa. Where water is physically scarce river basins are over-allocated, that is 'closed' or 'closing'. A closed river basin is one where there is no usable outflow during large parts of the year: in other words, the river does not reach the sea anymore. In a closed river basin, any new water resources development — whether it is an upstream dam for irrigation, a transbasin diversion from a middle reach, or an increased allocation to a city at the mouth of the river —takes away water from another human use. The only way to get 'more value' out of water in a closed basin is to shift water from lower-value uses to higher-value uses.

Physical water scarcity is often experienced through the characteristics of closed basins:

- they are over-allocated: there is little water left for environmental flows and there is more pollution
- the key issue in closed basins is 're-allocation': new developments invariably lead to reallocation — robbing Peter to pay Paul
- any new entitlements require re-negotiation of rights.

Examples of closing and closed river basins are Yellow River (China), Colorado River (USA), Amu and Syr Darya Rivers, Aral Sea drainage basin (Central Asia), Murray–Darling (Australia), Egypt's Nile, Lerma–Chapala (Mexico), Jordan (Jordan, Israel, Palestine), Gediz (Turkey), Zayanda Rud (Iran), Indus (Pakistan, India), Cauvery (India), Krishna (India) and Chao Phraya (Thailand).

Water scarcity in Australia

In a first for Australia, 66% of the citizens of Toowoomba voted in 2006 not to drink recycled wastewater. Still, the Premier of Queensland remains convinced that drinking recycled wastewater is inescapable. It is true that a survey carried out by the International Water Management Institute shows that 66% of Asian and African cities already re-use wastewater, often with limited or no treatment. It is not re-used for drinking, however, but to grow food. Vegetables, often, or fodder for dairy cows.

Australia is going through one of the worst droughts on record and that has made water scarcity a subject of major political interest. Cities contemplate desalination, drinking recycled water and massive infrastructure to pipe water to cities for domestic use. Is this really necessary?

The Murray–Darling River basin system is indeed closed. This has led to what is internationally seen as very advanced and forward looking water policies and decisions, but in Australia the public's impression appears to be that water is in a mess. Australia was the first in (a) imposing a cap on further development in the basin; (b) making water tradable among agricultural water users; and (c) planning to buy back water from agriculture to return it to nature.

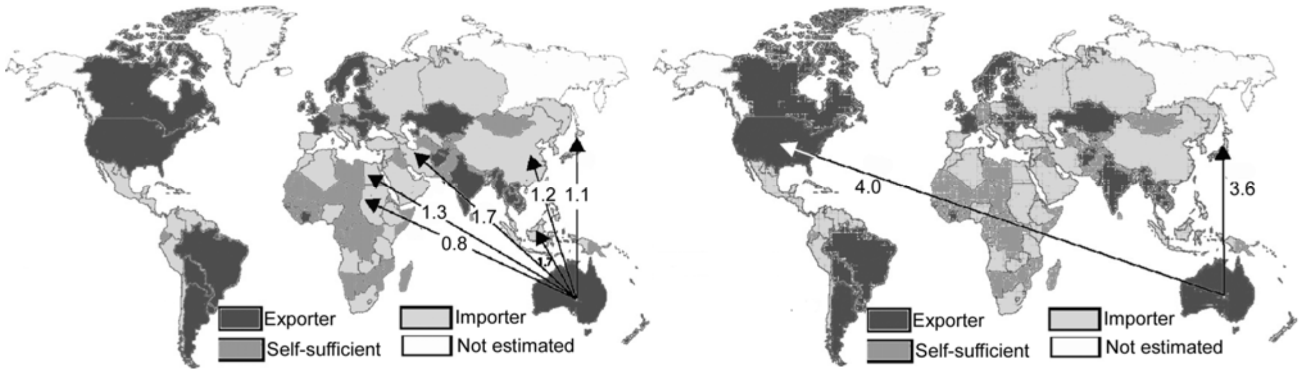
In early 2007, the cost to River Murray irrigators for buying water on the temporary market has shot up from about AU$0.04 to AU$0.40 per kL (or from 40 to 400 $/ML), which is indeed very high by international standards. At the same time, inhabitants of Adelaide still pay only AU$0.50 per kL for the first 125 kL, and a bit over a dollar for anything over that. That is a very modest amount by international standards (see Table 3) — though other cities in Australia such as Sydney and Melbourne are more in the international low to medium range of AU$2–2.5 per kL. It would appear unavoidable that prices for urban water in Australia, given its water scarcity, will go up to AU$3–4 per kL to become sustainable.

At the same time, there is no need for panic, or desalination, or drinking recycled water, as long as the country still exports 25 billion kL of virtual (agricultural) water embedded in wheat and beef (see Fig. 5). Diverting only a small part of the (irrigated) share of this water to cities would be a much more sensible solution than desalination. Transfers of water from irrigators to urban users make sense in Australia, wherever the geography allows it, and would appear inevitable.

Most of the water embedded in wheat and beef is from rainfed agriculture, so not directly competing with other users for irrigation water. When in Australia last year, I was frequently asked whether water scarcity will cause Australia to import food. That is highly unlikely. Some severely water-scarce countries do not have enough water to grow their food and need to import food. That is what Egypt does; it imports over half of its food, as it lacks the water to grow it domestically. It imports food from countries like the USA, Argentina, Brazil and Australia — where large amounts of water are converted into food and exported. Australia may have to export a bit less food and the water associated with it, or continue shifting to higher-value outputs that justify the new scarcity values of the resource, as has already happened in two cycles so far (first for sheep and then for wheat and beef). In other words, Australia is very far away from having to import staple food crops. It will have to manage its demand for water better, though, and part of that package is, again, better pricing. It could also expand water trading across sectors such as between farmers and cities where they are close, such as in Adelaide (e.g. Young *et al.* 2007).

Where to find the water to meet all the needs?

Traditionally, discussions of 'renewable water resources' take only that share of the rainfall that runs off into rivers and percolates into the groundwater. Worldwide, that is about 40% of all rainfall; the other 60% infiltrates into the soil and stays there until it is either evaporated into the atmosphere, or removed by plant roots and transpired into the atmosphere.



Virtual water exports, 10 km^3, embedded in 17 million tonnes of wheat in 2004

Virtual water exports, 15 km^3, embedded in 1.5 million tonnes of beef in 2004

Figure 5. Australia exports 25 km^3 (billion kL) of water per annum, embedded in wheat and beef (Source: de Fraiture *et al.* 2004)

In a dry country such as Australia the renewable water is even less, only 11–12% of rainfall. For urban water managers it makes sense to ignore the rainfall that becomes soil moisture — as this water cannot be piped into cities for domestic use — but for agriculture and the environment this water cannot be ignored. Soil moisture is the source of water for all rainfed agriculture and for ecosystems as well.

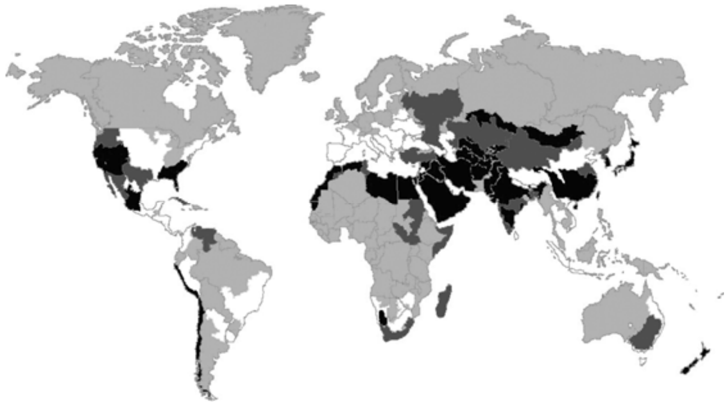


Figure 6. World map of dependence on 'green' water (rainfed soil moisture; white and light grey) and 'blue' water (from streams or storage; black and dark grey) for food production. The bulk of the world's food production depends on green-water agriculture.

To distinguish between the traditional definition of renewable water resources, that water is sometimes referred to as blue water, while the soil moisture is referred to as green water. Blue and green water together make up the complete hydrological cycle, i.e. all the rainfall. While the productivity of agricultural land, on average, roughly doubles when it becomes irrigated, the largest part of the world still relies on rainfed agriculture for the production of its food (see Fig. 6). There are three main options for finding the water to satisfy human demands, particularly to grow food and to provide a living to the 70% of the world's poor people for whom poor access to reliable, safe and affordable water for food and livelihoods is a poverty trap, i.e. the poor in rural areas. These are to:

1. expand irrigated areas — divert more 'blue water' from rivers and aquifers
2. expand rainfed areas — turn more natural area into arable land — use more 'green water'
3. increase water productivity — produce more with less water, i.e. more crop per drop.

The key water resources development strategy in Asia and some OECD countries has been to build dams, divert water to irrigated agriculture, and intensify production. This was, particularly in Asia, the achievement often referred to as the Green Revolution that was a combination of improved varieties, increased (chemical) fertiliser use, and irrigation. In Asia, there were few other options because the population density in many countries implied that there was no land left to convert to agriculture. In Africa, on the other hand, the key strategy has been to expand the area under agriculture, with very little irrigation or agricultural intensification. In Latin America there has been a mixed strategy, with a few countries investing in large-scale irrigation (such as Mexico and Brazil) while others (and Brazil) mainly expanded the area under agriculture.

Very few countries, with the very notable exceptions of Israel early on and Australia more recently, focused deliberately on the third option, i.e. to deliberately increase the productivity of water — to grow more with less. When we focus on a farmer's field, then to increase water productivity is equivalent to getting 'more crop per drop'. As soon as that farmer also has livestock, or a fishpond, however, the definition of water productivity has to include the other uses of water. At the river basin scale, water productivity needs to be understood in the widest possible sense, including crop, livestock and fishery yields, ecosystem services, as well as social impacts such as on health, together with the systems of resource governance that assure an equitable distribution of these benefits.

Typical water productivity (relative to evapotranspiration) figures for staple cereal crops (rice and wheat) are:

- typical low-performing irrigation system: 0.5 kg / m^3 (kL)
- state-of-the-art irrigation system in Asia: 1.5 kg / m^3
- rainfed systems in Sub-Saharan Africa: 0.2 kg / m^3
- best rainfed systems in Europe / North America: 1.8 kg / m^3.

To meet the projected agricultural demands for water into the future, the consensus among scientists is that while there is some scope for expanding irrigation, the key strategy will have to be to increase water productivity (CA 2007). Unlike in past decades, however, when the focus was on increasing the productivity of irrigated agriculture, more recent thinking is that the low-productivity rainfed systems in Africa's savannahs offer the greatest scope for productivity increase through improved water management, through various approaches from the use of shallow groundwater, to rainwater harvesting, to the development of drought-resistant plant varieties.

Priorities for water productivity improvement

The water, food and environment theme document for the 4th World Water Forum in Mexico in March 2006 proposes the following priorities for action (Rijsberman and Manning 2006):

1. Increasing blue water productivity — getting the most out of renewable water resources:
    a. improving irrigation management
    b. adapting farming practices to increased water scarcity
    c. enhancing the safe and productive use of wastewater in irrigated agriculture
    d. promoting multiple-use systems: single systems for domestic use, agriculture, aquaculture, agroforestry and livestock.
2. Increasing green water productivity — making the most of soil moisture:
    a. rainwater harvesting
    b. supplemental and micro-irrigation
    c. increased infiltration and reduced run-off through better land and water conservation.
3. Increasing access to water resources — investing in water resources developments that are crucial to achieving MDGs in Africa:
    a. coping with climate variability requires investments in water storage, through large and small dams
    b. understanding that farmers are the private sector and will invest in water and land development, management and conservation wherever this is a viable business proposition
    c. ensuring that returns to agricultural water investments increase with access to markets and when combined with hydropower, livestock, aquaculture or drinking water
    d. making an asset out of wastewater holds the promise of making sanitation affordable for poor people.
4. Balancing water for food and other ecosystem services — giving voice to the silent actor:
    a. securing water for the needs of the environment
    b. enhancing benefits in agriculture–wetlands interactions
    c. managing agricultural water use sustainably: ignoring environmental impacts can lead to failed projects.
5. Investing in water security for poverty alleviation — targeting poor areas with pro-poor designs:
    a. targeting geographic areas with high concentrations of poverty and focus on pro-poor project design
    b. implementing gender-equitable development boosts productivity
    c. requiring ex-ante poverty impact assessments for water resources investments.

The Comprehensive Assessment of Water in Agriculture proposes the following eight policy actions (CA 2007):

1. Change the way we think about water: instead of a narrow focus on rivers and groundwater, view rain as the ultimate source of water that can be managed.
2. Fight poverty by improving access to agricultural water and its use: target livelihood gains of smallholder farmers by securing water access; improve the value obtained by water use through pro-poor technologies, and invest in roads, markets and water storage where needed — multiple-use systems can improve water productivity and reduce poverty.
3. Manage agriculture to enhance ecosystem services: good agricultural practices can enhance ecosystem services.
4. Increase the productivity of water: more food can be produced with less water in all types of farming systems — with special attention for livestock systems; with careful targeting the poor can benefit from water productivity gains.
5. Upgrade rainfed systems: a little water can go a long way by improving moisture conserva-

tion and supplemental irrigation, especially in Sub-Saharan Africa and parts of Asia, with high potential for mixed crop and livestock systems.

6. Adapt yesterday's irrigation to tomorrow's needs: the era of rapid irrigation expansion is over, but much can be done with modernisation and institutional reform.
7. Reform the reform process — target the state: a major policy shift is necessary and the state water institutions responsible for reform are themselves often the most in need of it; breaking down the divide between rainfed and irrigated agriculture and better linking with fisheries and livestock management.
8. Deal with trade-offs and make difficult choices: informed multi-stakeholder negotiations are essential to negotiate decisions about use and (re-)allocation.

Conclusions

We cannot escape the fact that as water scarcity increases, the price of water is bound to go up. People will pay, if they have to, up to the value they get out of the use. That is why cities and industry, where the value they get out of the water use is measured at least in dollars per cubic metre, easily out-compete agriculture almost everywhere. Where urban water prices are still less than several dollars per cubic metre, they are likely to go up to this level. The value or productivity of water in agriculture varies from several cents per cubic metre for most grain crops up to as much as a dollar for intensive vegetable production. As water gets scarcer, it no longer makes sense for society to use it to grow crops with a water productivity of only cents per cubic metre, if the value in nature is more. Of course, as long as the price farmers pay for water is less than what they get out of it, they will keep using it.

If farmers don't pay a fair price for water, over-use is the likely consequence and nature pays the price. Research can help determine the value of water in alternative uses, even for nature. Agricultural research also works to increase the value of water in agriculture. A combination of smart engineering and agronomy, for example, can drive the volume of water needed to produce a kilogram of rice down from 2000 to as little as 500 litres. To keep agriculture competitive and sustainable, a 50% increase in the productivity of water in agriculture will be necessary — and feasible — worldwide over the next two decades. Increasing the value people get out of water will help them prepare for price increases.

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