Water
for a growing planet

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Contents

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ONE: INTRODUCTION

Water for food, water for life, the International Water Management Institute's (IWMI) comprehensive assessment of water in world agriculture opens with the following question:

"Is there enough land, water and human capacity to produce food for a growing population over the next 50 years - or will we 'run out' of water?"

Strictly speaking, the Earth can never run out of water thanks to the water cycle, which describes the process through which water is recycled between air, land and sea. Water from rivers, lakes and oceans evaporates into the atmosphere to form clouds and vapour, which then falls back to Earth in the form of rain, sleet and snow. In reality, the water that is commonly described as being 'lost' is in fact water over-use from one part of the cycle.

The report's answer tries to be both optimistic and at the same time realistic: it is possible to produce enough food if populations learn to use water more efficiently, and through technological innovations such as developing food crops that can grow using less water. However, the report also adds that: "It is probable that today's food production and environmental trends, if continued, will lead to crises in many parts of the world."

Such crises are already a daily reality for many. Today, 742 million people in rural areas and 137 million in urban areas lack proper access to an improved source of clean water. Moreover, around 2.5 billion people lack access to improved sanitation in their homes. In addition, some 2.8 billion live in river basins at risk of water scarcity. Of these, 1.6 billion live in areas where water exists, but is not available to those who need it; and 1.2 billion people live in areas where the demand for water exceeds what is available. [1]

If current trends continue, the numbers without access to safe water will increase from 1.2 billion to nearly 1.4 billion by 2020. As population grows, the numbers who will die from water-related diseases will also increase - projected to reach 2.6 million per year under business-as-usual. [2]

Addressing the World Economic Forum in Davos in March 2008, UN Secretary General Ban Ki Moon said: "A shortage of water resources could spell increased conflicts in the future. Population growth will make the problem worse. So will climate change. As the global economy grows, so will its thirst. Many more conflicts lie just over the horizon."

Table 1: Who uses what
Water use by agriculture, industry and households (%)

	Agri	Industry	Households
Less developed countries	81	11	8
Developed countries	46	41	13
Worldwide	70	20	10

Source: *Water for food, water for life [6]*

Worldwide, some 850 million people, are undernourished - unable to produce or buy enough food, nor likely to have access to safe and affordable water and sanitation. Many of those likely to suffer in many of the above scenarios live in the rural areas of Africa and Asia. They are most likely to be subsistence farmers, earning their livelihoods directly from the land they occupy. However, equally vulnerable are many of the 50 per cent-plus of the world's population who now live in cities. Africa's urban population alone is expected to reach around 500 million in 2020 - up from 138 million in 1990. [3]

In most parts of the world, the demand for drinking water and for water for irrigation and industrial needs is largely being met from groundwater resources. These resources, however, are depleting and the reasons include population pressures as well as the demands from economic development. Pollution and increased salt content of groundwater resources is also increasing.

In 2002, the UN and the international community of water experts announced a goal - part of the Millennium Development Goals - to reduce in half by 2015 the numbers of people unable to reach (or afford) safe drinking water and basic sanitation. This remains a bold and an ambitious target and it needs both large sums of money, innovative new ideas, and urgent practical action. For example, in order to reach the goal, every day, some 340,000 water connections need to be installed, as well as 460,000 sanitation units.

Progress is slow and the expert consensus is that the Millennium Development goal is unlikely to be met. Among the many reasons is a lack of financial commitment - which has been falling since the targets were announced, if not before.

Between 1996 and 1998, international donors spent $3.5 billion on water supply and sanitation projects. Between 1999 and 2001, this figure had fallen to $3.1 billion. International assistance to agricultural research and development - once 16 per cent of the total spend, is now close to 4 per cent. At the same time, however, warnings on the state of the world's water continue to grow louder. [4]

At the same time, however, there are one or two bright spots on the horizon. Conventional wisdom, for example, suggests that greater economic growth and rising populations equals more water use. But (at least in the case of China), national prosperity does not seem to be putting extra demands on freshwater supplies. Whereas China's GDP has been increasing steadily since 1952, the country's water use appears to have reached a peak of 563 billion cubic-metres in 2000. [5]

Table 2: China satisfied?

Year	GDP Index	Water use billion m^3
1952	100	100
1959	205	200
1969	250	300
1980	547	444
1990	1333	500
1997	2745	563
2000	3422	550

Source: The world's water: 2002-2003 [5]

This present work draws on much of the latest literature, in particular the work of Peter Gleick, Philip Pardey, as well as the findings from the UNDP 2006 Human Development Report *Beyond Scarcity* and the long-awaited *Water for food, Water for life*, organized by the International Water Management Institute and edited by David Molden. A full list of data sources can be found in section 7.

The report also represents an urgent plea for more ambition, but backed by action. We need the kind of ambition that led to the first Green Revolution, and we need action to ensure adequate access for the peoples of the developing world at a time of rapid demographic change, rising needs for food and fuel, economic insecurities, rapid urbanization and global climate change. In short, we need better governance and better management of the water cycle.

TWO: **WATER FOR FOOD AND ENERGY**

2.1 Our changing diets will need more water

Urbanization has the potential (in the long-run) to reduce agriculture's share of water withdrawals. But people still need to be able to eat and drink - regardless of whether they live in cities or on the farm. This tells us that agriculture's share of water use - around 80 per cent in developing countries, and more in the most arid regions - is unlikely to fall, and that more water will be needed to produce more food and different kinds of food for more people.

In 1970, an average diet in the developing countries consisted of 2,400 kilocalories. In 2000, that figure was closer to 2,800. [6] In many countries, diets that would have once consisted mostly of bread, lentils, rice and a small number of staple vegetables, now also include more milk, cheese, butter, meat, poultry, fish, soft drinks and other examples of processed food, as well as more traditional staples.

As our diets change, so, too is our impact on water. One kilogramme of grain requires between 500 and 4000 litres of water (depending where it is grown). A kilogramme of meat needs between 8000 and 12000. The International Water Management Institute says that up to $6m^3$ of water is needed to produce 1kg of poultry, $10m^3$ of water is needed for 1 kg of lamb and $15m^3$ of water is needed to produce 1 kg of grain-fed beef. [7] Despite large variations, on average we use a litre of water for every calorie in our diets [8]

So how much more water are we likely to need?

Agriculture uses water through what is called 'evapo-transpiration': that is transpiration through plants and evaporation from the soils as well as direct uptake by plants. Globally, 80 per cent of this water consists of 'green water'. This is rainwater that is stored in the soil. The remaining 20 per cent is 'blue water'. This is water that has been diverted from rivers, reservoirs, lakes and aquifers.

IWMI predicts that, without any further increases in water productivity, the world in 2050 will need approximately double the current quantity of both blue and green water. Today, that figure stands at 7,130 km^3. In 2050, it is likely to rise to between 12,000 and 13,500 km^3, unless more work is done to increase the productivity of crops from rainfed agriculture. [9]

2.2 Biofuels: solving the energy crisis by creating water shortages?

Independent assessments tell us that the world's demand for energy will increase by at least 70 per cent by 2030 and that three-quarters of this increase will come from developing countries. Energy sources will be a mix, dominated by fossil fuels, but also including nuclear energy, hydropower and other renewables. Each of these will have an impact on water - especially biofuels.

Currently, the world consumes 1200 billion litres of fuel for transport annually, of which two per cent comes from biofuels. This figure will increase in the coming years because governments across the world are determined to convert more of the transport sector into using biofuels. For example, the European Union wants 5.75 per cent of transport fuels to come from biofuels by 2010. The US wants 28.4 billion litres of biofuels in the transport sector by 2012 and Brazil wants all diesel fuels to contain five per cent biodiesel by 2013.

Table 3: Biofuels wanted

Government targets for biofuels as a share of transport fuels by 2030.
2% is the current world average

Brazil	65%
EU	10
India	10
China	9
US	5
Indonesia	2
Africa	2

Fuels manufactured from plants are of course not new - indeed the first internal combustion engine was powered from vegetable oils and fuel sources such as wood and charcoal are in effect biofuels. The newer biofuels come in three main varieties: bio-ethanol, bio-diesel and bio-gas.

Bio-ethanol can be made from sugars as well as grains such as maize and wheat, from grasses and even food-waste. In existing motor vehicles, the fuel mix can include up to 10 per cent bio-ethanol. Newer vehicles are able to use any proportion of bio-ethanols. The US and Brazil together produce 70 per cent of the world's bio-ethanol. Brazil uses mostly sugarcane, whereas in the US the source is mostly maize and some soya.

Bio-diesel, in contrast is made from oilseed crops, such as rapeseed, or an oil-bearing crop called jatropha. Ninety per cent of the world's biodiesel is produced in the European Union - mostly in Germany, France and Italy. Jatropha planting, however, is likely to increase in developing countries as it can be grown on degraded land that is not suitable for food production. India, for example, has 60 million hectares of waste land, half of which could potentially be used to produce jatropha.

What will be the impact of these increases on water?

It takes on average 3320 litres of water to produce 1 litre of biofuel – 2,500 litres of rainfed water, and 820 litres from irrigation. At the present time, the world's combined agricultural production requires 7130 km^3 of water. Biofuel crops at present account for an additional 100km^3 - an increase of around 1.4 per cent. [10]

However, biofuels production doubled between 1990 and 2002 according to IWMI, and is projected to double again by 2010. By 2030 (on current projections), biofuels will need an additional 180 million tonnes of maize, 525 million tonnes of raw sugarcane and 50 million tonnes of oil crops. These will be met by an additional 30 million hectares of land, and 128.4 km^3 of irrigated water.

There are of course other impacts from the growth in biofuels. One is increased prices for those commodities that will not be grown if additional land is to be allocated for biofuel growth. Brazil, however, may be an exception to this rule since it uses sugar cane and since the country has very large lands in The Cerrado that can be brought under cultivation. . Another impact will be on feedstock prices. According to the World Bank, the US ethanol programme is chiefly responsible for a 60 per cent of the rise in maize prices between 2005 to 2007.

Table 4: Biofuels and water projections for 2030

	Biofuel production (billion L)	Crop	Irrigated water needed (km^3) for biofuels	% total irrigated water used on biofuels
US/Canada	51.3	Maize	36.8	20
Brazil	34.5	Sugarcane	2.5	8
EU	23.0	Rapeseed	0.5	1
China	17.7	Maize	35.1	7
India	9.1	Sugarcane	29.1	5
South Africa	1.8	Sugarcane	5.1	30
Indonesia	0.8	Sugarcane	3.9	7

Source: International Water Management Institute [9]

What of the future? Future biofuel technology may rely on dedicated energy crops and on agricultural and timber waste instead of food crops, potentially reducing the pressure on food crop prices. These 'second-generation' technologies can convert cellulose waste products into sugars, which can be distilled to produce ethanol. However, the *OECD/FAO 2007-2016 Agricultural Outlook* predicts that these technologies are at least a decade away from commercial application.

Table 5: Biofuels and food prices
% increase in food prices from two scenarios of biofuel growth

Without technology improvements			**With cellulosic biofuels**
Crop	*2010*	*2020*	*2020*
Cassava	33	135	54
Maize	20	41	23
Oilseeds	26	76	43
Sugar beet	7	25	10
Sugar cane	26	66	43
Wheat	11	30	16

Source: International Food Policy Research Institute [11]

2.3 Hydropower: a cleaner alternative for the developing world

An important use of water is to produce electrical energy. Faced with the challenge of reducing CO_2 emissions, all feasible alternatives to produce energy must be considered. Unlike the production of food or biofuel, hydropower does not consume water. That is, after producing electrical energy, the water is still available for other uses. Hydropower accounts for only 19% of all the electrical energy produced in the world today. It would be technically feasible to produce an estimated 6,500 Terra-Watt-hours per year of hydropower globally, yet only a third of that capacity is exploited. Most of the new hydropower plants will be built in Asia.

Table 6: Hydropower on different continents (Terra-Watt hours per year)

Region	Current output	Current output as a % of total potential output	Total potential output
Europe	570	72%	792
North America	700	69	1,014
South America	550	35	1,571
Africa	80	7	1,143
Asia	800	22	3,636
Australasia	43	49	88
Total	2,743	~	8,245

Source: International Hydropower Association

Europe and North America have developed more than 70% of their hydropower potential. In developing countries in Asia, Africa and Latin America, more than 70% remains untapped. Africa, for example, has developed only 7% of its hydropower potential.

The most successful economies in the next 50 years, according to the investment bank Goldman Sachs, will be Brazil, Russia, India and China – known collectively as BRICs. The hydropower potential of these countries is enormous. As the table below shows, they will need to make the most of this potential to achieve a new stage of development.

Like any other form of energy generation, hydropower has an impact on the environment. It reduces river flow and the dams obstruct fish migrating upstream to spawn. It can also have a human impact: the lake formed by the construction of the 24,000 MW Three Gorges powerplant in China has displaced more than 1 million people.

Thanks to the campaigning work of NGOs, governments all over the world have been made aware of the need to consider these issues when developing dams. Many developing countries now have strict environmental legislation covering the environmental and social impacts of dam-building. In Brazil, for example, the penalty for not complying with measures imposed by the environmental agency is jail without bail.

With environmental and social safeguards in place, hydropower is a sustainable alternative for coping with the challenge of climate change, especially for developing countries of southeast Asia.

THREE: WATER FOR OUR GROWING CITIES

The cities of the developing world are experiencing an extraordinary period of change. Up until very recently, some of the economies of Asia were growing at 8 per cent per year, and many in Africa at 6 per cent or more. At the same time, a greater proportion of the world's population now lives in cities and migration trends remain strong.

This increased urban population is causing problems for cities of the developed world as they struggle to cope with the legacy of old centralised systems and a lack of maintenance. More significantly, it is placing heavy pressure on the urban infrastructure of developing countries which already suffers from severe under-investment. Yet in spite of this, some sections of developing-country cities are becoming more prosperous, and a small (but increasing number) of city-dwellers are experiencing better roads, reliable energy and transport, good standards of healthcare, education, even water supply.

Many of these improvements are being felt because the demand for better services is being met mainly by private enterprise.

The water infrastructure of developing-country cities is a case in point. In many large cities, municipal water supplies are unsafe. In addition, corroded and leaky pipes prevent up to 40 per cent of water from reaching its destination in many cities of Asia and Africa. [12] In Nairobi for example, the quantity of water that leaks out from damaged municipal pipes, could easily supply the whole of Mombasa. As a result, many businesses and more prosperous households have established their own systems for obtaining water and they are prepared to pay for private water-tankers to provide water for washing and cleaning, and to use bottled water for drinking and cooking.

3.1 Informal water vendors: the outlaws who save lives

When it comes to discussions on water and cities, the ubiquitous private water vendor is the elephant in the room. In the large cities of Asia, less than half of households have access to a piped water connection. In a survey of eight cities carried out in 2001, the Asian Development Bank found that 7 million people (one in five of the population) were paying private water vendors for a myriad of services. [13]

These include fixed sources such as community standpipes, communal taps, or mobile vendors who deliver small quantities of water to their homes. For residents with a little more disposable income, more money can pay for a water tanker, a regular supply of bottled water, a direct connection using flexible hosepipe, even drilling a borehole for access to groundwater. According to the bank, up to one in five in many large cities in Asia drink bottled water because they do not trust the quality of municipal supplies.

Informal water vendors effectively extend the coverage of the piped water network by reaching those households and localities not covered by the network for various reasons. Without their services, these households and localities would not be able to access good quality water for drinking and for domestic use. The most important advantage of informal water vending is that households who are unable to buy water connections and who set aside larger quantities of money to pay bills are able to purchase small quantities of water on a daily basis according to what they can afford.

Bottled water sales continue to grow rapidly. As of 2006, total annual sales were estimated to be between $50 billion and $100 billion. Five of the ten largest consumers of bottled water are developing countries (Mexico, China, Brazil, Indonesia and India). Italy has the largest per capita use of bottled water at 184 litres per person per year (there may be cultural reasons for this). Asia and Latin America meanwhile, have seen bottled water sales treble since 1997. [14]

The advantages of private water services to households are clear. However, the status of informal water vendors varies from country to country. In some, vendors are completely illegal; in others, they operate within the law. In some countries, they are accepted but do not have legal status and in others still, they are recognized as meeting an important need but operate without any contracts between themselves, their customers and the regulators, municipalities or water utilities. Where this is the case, there is little or no guarantee of service, particularly as the vendors are also likely to be closed down at any time. From the viewpoint of the water vendors, inspite of the demand from consumers, the risk of fines and closure makes it is difficult for entrepreneurs to create businesses. Banks are reluctant to lend money, which makes access to credit much more expensive than it should be.

A second problem is that, even under existing unregulated private services, there are still many, many residents of cities who cannot afford to pay for even the most basic provision. The tragedy for this group is that as more and more fee-paying customers choose to obtain water from private sources, there is even less likelihood of improvements to the public infrastructure. An additional constraint is that public authorities are refusing (or are unable) to charge a realistic price to those of their customers who can afford to pay.

Table 7: Households in Asia with piped water connections

		Population (m)
Delhi	46%	14
Dhaka	10	11
Karachi	47	16
Manila	32	20
Jakarta	31	9

Source: Asian Development Bank [13]

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Table 8: Water in a bottle
Ten largest consumers of bottled water (thousand cubic metres per year)

	2003	2004
USA	24,199	25,893
Mexico	16,495	17,683
China	10,628	11,894
Brazil	10,758	11,598
Italy	10,350	10,661
Germany	9,950	10,313
France	8,907	8,550
Indonesia	6,945	7,362
Spain	5,098	5,506
India	4,202	5,126

Source: The world's water [14]

3.2 Toxic wastewater needs to be treated

Wastewater from cities is an important source of water for irrigation in most developing countries where wastewater is collected by both public and private sectors. If treated correctly, wastewater in agriculture can help to reduce fertilizer costs as it contains crop nutrients such as nitrogen and phosphorus. But untreated (or partially treated) wastewater can also contain heavy metals, which enter the food chain via irrigated agriculture.

In a survey of wastewater in 53 cities published in August 2008, the International Water Management Institute says that people in 42 out of 53 cities in Africa, Asia, Latin America and the Middle East are eating food that has been grown using contaminated wastewater. In more than 70 per cent of the cities studied, half of urban agricultural land is irrigated using raw wastewater or wastewater that has been diluted from streams. [15]

This confirms what many experts have long-suspected: that untreated wastewater from households and from industry is finding its way into the food chain; and that this is contributing to health problems, such as skin disorders and diarrhoeal infections. In two-thirds of the cities surveyed by IWMI researchers, wastewater from toilets, household kitchens and from industry was mixed together before being discharged back into the environment.

Policymakers in developing countries are well aware of these problems, but only in a minority of cases is anything substantial being done. India's urban areas, for example, generate 30 billion litres of sewage daily, yet the country has the capacity to treat at most 10 per cent of this. Ninety per cent of untreated sewage is still being discharged directly into the environment, mostly in lakes and rivers. Similarly, China's water resources ministry acknowledges that more than half of the water in the country's river systems is unfit to drink, and the government wants 9 out of 10 cities to be able to process more than 60 per cent sewage waste by 2010, instead of discharging it directly into the environment. [16]

It is worth noting that communities and countries will need to invest in and manage basic infrastructure such as water, sanitation, energy and transport to be sure of healthy and sustainable economies in the future.

FOUR: WATER AND THE IMPACTS FROM CLIMATE CHANGE

Predicting the impact on water from human-induced climate change is an uncertain business. Scientists make their predictions using computer models of past and future trends for temperature, precipitation and soil moisture. Of these three variables, records for temperature and precipitation are relatively good. But data on soil moisture is poor.

What we know with some certainty is that climate change will make dry areas drier and wet areas wetter. Climate change, moreover, will interact with the Asian Monsoon and the El Nino Southern Oscillation. Rising sea-levels and shrinking glaciers will both affect the availability of freshwater and also contribute to an increased risk of flooding.

Although global modelling of the impact of climate change on rainfall and water availability is increasing in overall accuracy, it is still set at too large a scale to understand local impacts. Thus it is essential that additional efforts be deployed for modelling at the regional level to provide a more accurate context for local action. This should be deemed an important national and international priority.

4.1 More droughts, more rainfall

In the case of drought, extreme summer heat dries up the soil early in the year; and this dry soil makes the heat more intense. The subsequent reduction in soil moisture will lead to erosion, more surface runoff (less water absorbed in the soil) and a change to soil nutrients. The regions believed to be most at risk from drought are North America, sub-Saharan Africa and North India.

Existing drought statistics make sobering reading. Some 10 million people died from the effects of drought between 1900 and 2005. Eight droughts accounted for 97 per cent of reported deaths - all in the developing world. Droughts do occur in developed countries, though tend to be less prolonged and have far fewer deaths. [17]

In the case of rainfall, climate scientists predict that more rain will fall, but less often. In addition to the possibility of flooding, this is likely to lead to a situation in which soil is either waterlogged, or depleted of moisture for longer periods.

Some seven million people died from floods between 1900 and 2005. Nine in ten deaths came from five floods that all occurred in China before 1960. Some 300,000 are believed to have been killed from a series of tsunamis following an earthquake off Sumatra in December 2006. As in the case of droughts, flooding is not restricted to the developing world, but the vast majority of flood-related deaths happen in developing countries. [18]

The Intergovernmental Panel on Climate Change predicts three additional impacts on water from climate change. The first of these is more insecurity for those who rely on rain-fed agriculture. The second impact is an inability to be able to predict weather patterns with any degree of precision, leading to more insecurity. The third is falling agricultural productivity in parts of the developing world.

4.2 Insecurity for rain-fed crops

The majority of the world's agriculture is rainfed, but farmers who rely on the rains for their crops are the ones most likely to suffer from drier soils (as well as from flooding). One analysis of the climate risks of crops in 12 regions of the world showed that oilseed rape, maize and wheat in south Asia and in sub-Saharan Africa will be the most vulnerable crops and that by 2080, an additional 75 million to 125 million people dependent on these farming systems are likely to become malnourished. [19]

Sub Saharan Africa is likely to be worst hit. Some 300 million people depend almost entirely on rain-fed agriculture. According to one IPCC scenario climate change could lead to a drop in agricultural productivity of at least 25 per cent for countries in the Sahel belt, as well as Nigeria, Senegal, Sierra Leone, Ethiopia, Somalia and many countries in southern Africa. [20]

In eastern Africa, maize productivity is predicted to fall by 33 per cent, and Kenya could see a similar drop in productivity of coffee and tea. Sudan could see a drop of between 20 and 76 per cent for sorghum and a fall of between 18 and 82 per cent for millet. [21]

But this does not have to be the case. With good policies, investments and practices, it is still possible to raise productivity levels despite climate change.

4.3 Retreating glaciers, rising sea levels and saltwater intrusion

Glaciers are the central banks of the water world. They store water in the form of ice and snow in the winter months, and release it slowly into rivers and lakes as temperatures increase. Glaciers are an important source of water for drinking and for agriculture. But thanks in part to climate change, glacial banks are experiencing problems holding onto their capital.

In the 1990s, all of the world's major glaciers experienced what is called glacial retreat - and at a rate around three times as fast compared with the previous decade. In the first half of the 21st century, river flows will increase, leading to an increase in run-off and flooding. In the second half of the century as glaciers disappear, the opposite is likely to happen, with river-flows increasingly dependent on unpredictable rains and in places falling by at least 30 per cent. These changes will fundamentally change the capacity of ecosystems and have a direct impact on the wealth of populations in the affected regions. [22]

Rising sea levels is another of the consequences of global climate change. Among the impacts of this is less freshwater and more coastal flooding. Bangladesh, Egypt, Nigeria and Thailand are likely to be affected the most, as they have large populations living in delta areas that will suffer from an intrusion of salt-water from the seas and rising sea levels by the end of the century. [23]

It is worth observing that it is not only sea level rise that makes soils saline - improper irrigation is also a factor, notably in Mesopotamia, India and Pakistan, and many hundreds of hectares are lost each year because of this. Another factor is reduced flow of rivers into the sea, which does not "wash out" the salt from the land, and also allows salt water to creep inland.

FIVE: WHAT PRICE RESEARCH AND DEVELOPMENT?

Towards the end of the 20th century, the nations of the developed world embarked on a process of change in agricultural research and development (R&D) whose consequences are now being felt by rich and poor.

Four developments dating back from the early 1980s are significant. First, the private sector became more dominant in agricultural R&D and more materials and processes that could be of public benefit became subject to intellectual property protection. Second, an increasing share of public R&D spending was earmarked towards research geared at environmental issues, food quality and food safety - at the expense of traditional fields such as crop improvement.

Third, agricultural biotechnology research in the European Union (except in the area of biosafety) was cut back because of public fears over genetically-modified foods. And fourth, spending on agricultural R&D as part of development assistance to the poorest countries began to fall - from 16 per cent in 1980 to 4 per cent in 2003. Donor assistance to the Consultative Group on International Agricultural Research has been static since 1990. [24]

At the same time (and possibly as a consequence), the larger developing countries took steps to strengthen their agri-research systems. And by 2000, more than half of the world's $23 billion public sector agricultural research bill was picked up by developing countries. [25]

However, just five developing countries (Brazil, China, India, South Africa and Thailand) dominate the spending. A further 80 (representing some of the poorest) contributed just 6 per cent, and 13 African countries spent less on agricultural research in 2000 compared with what they spent in 1991. [26]

Taken together, these developments have contributed to a slowdown in the rate of advancement of knowledge on water and agriculture. One immediate impact of this is that the scientific community finds itself ill-equipped to respond to the current food crisis. The public and policymakers are looking for urgent answers, but scientists are unable to do very much in the short term.

High priority needs to be given to increasing agricultural productivity on the majority of rain-fed fields in developing countries, which, *Water for Food; Water for Life* says is "often today no greater than that on the fields of the Roman Empire". Three-quarters of the additional food we will need over the next decades could be met by raising the productivity of the world's low-yield farmers to within 80 per cent of what higher-yielding farmers can obtain from comparable land.

Other solutions include improving soil fertility, improving the technologies of irrigation, improving access to irrigation, where this does not exist, and developing novel technologies, such as bio-fortification (which gave us vitamin-A-enriched Golden Rice), as well as technologies that could mimic plants that can exist in seawater.

SIX: **RECOMMENDATIONS**

1: Overall water situation

The water crisis is real and will become more serious faster than many imagine. The crisis is amplified by climate change, which is increasing the frequency, intensity and duration of extreme weather, such as floods and droughts. The Millennium Development Goals on water and sanitation are unlikely to be met without new thinking in all areas - especially financing, and in the longer term, better research.

2: Recommendations for specific action

- UNEP should organize a commission to review the report of the first World Commission on Dams of a decade ago in the light of new developments and climate change.
- Double the funding available for international agricultural research.
- Groundwater aquifers that cross international boundaries should be governed by international agreements in the same way that trans-boundary rivers and river basins are being managed.
- A special multi-donor fund to finance small projects would assist many local efforts. But this must not be mired in heavy bureaucracy or administrative overhead.

3: Recommendations for further research

- Refine the estimated impacts of climate change on rising sea levels, and specifically study the impacts on the most vulnerable countries. This could be a task for UNEP and the Intergovernmental Panel on Climate Change.
- Invest in developing "regional models" of climate change and its impacts, as these are key to link global forecasts to local actions.
- More study is needed to ascertain the extent and quality of the available groundwater and its current patterns of utilization. A global

assessment based on modern remote sensing technology should be a first step in this direction.

- Promote research into the next generation of biofuels. Explore using degraded soil in the tropics with cultivation of sugar cane, which is twice as efficient as corn in ethanol production.

- Develop crops that require shorter growing periods and plants that are less thirsty, and more resistant to drought and to salinity. More research to reduce the use of water in growing rice. Intensify research programmes in the possible uses of alternative plants such as halophytes that have direct uses as feed or food or fuel.

4: Broad recommendations

- Countries need to address the management of water and ensure that effective policies promote the optimum use of water resources. In particular, relevant policies should be reviewed to ensure that both polluter-pays and user-pays principles are in place.

- Countries need to recognize the need for public-private partnerships, while at the same time ensuring transparency and community involvement in such arrangements, where necessary. More transparency means less corruption and better water governance. Improving water management will require interaction between several sectors, including energy, transportation and agriculture.

- The potential for rainwater harvesting has not been realised in many parts of the world, and much can be done with low investment. For example, low cost and environmentally-friendly rainwater harvesting technology needs to be encouraged, such as underground aquifers that can store water, recharge existing aquifers, and promote the retention of soil moisture. Supplemental irrigation in rain-fed areas needs to be expanded.

- A significant effort is needed to raise the productivity of less efficient farmers, including training programmes, so that available technologies are used to much better effect than they are now.

- Revisit the biofuels subsidies programs that have been launched by the US and the EU to ensure that they really help promote that second generation of bio-fuels.

- Wastewater is an important source of urban food production, but often enters the food chain untreated. This needs to change. Industrial pollutants (such as heavy metals) need to be tracked and regulated to avoid their entry into the food chain.

- Desalination is a proven technology with a future. However, it is costly and its impacts on climate change and on the environment more generally need to be better understood.

- Upgrade the efficiency of municipal water systems, reduce pirate connections and unaccounted-for losses. Work with water vendors and mobilize their entrepreneurship in providing better services. Until public utilities are able to extend their coverage fully, services provided by private water vendors will be necessary for meeting the Millennium Development Goal to halve by 2015 the numbers of people unable to reach (or afford) safe drinking water.

- Expand the use of micro-credit for wells: 15 million have already benefited thanks to micro-loans from the Grameen Bank.

- Bio-industries need to be encouraged. In the longer term, these will be better for the environment than chemically-based ones.

SEVEN: DATA SOURCES

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EIGHT: LIST OF TABLES

NINE: CONTRIBUTORS

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