



## Chapter 5

# Climate change and possible futures

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### Key messages

- ◆ There is evidence that the global climate is changing. The main impacts of climate change on humans and the environment occur through water.
- ◆ Climate change is a fundamental driver of changes in water resources and an additional stressor through its effects on other external drivers.
- ◆ Policies and practices for mitigating climate change or adapting to it can have impacts on water resources, and the way we manage water can affect the climate.

Chapters 2-4 have described how external drivers exert pressure on water resources. These drivers of change are strongly interconnected, creating complex challenges and opportunities for water managers and decision-makers. Apart from extreme events (such as droughts and floods), climate change is seldom the main stressor on sustainable development, although the direct and indirect impacts of increasing climate variability can impede and even reverse development gains (see figure 5.1 for a depiction of climate change processes, characteristics and major threats). Climate change may not fundamentally alter most of the world's water challenges, but as an additional stressor it makes achieving solutions more pressing.

All of the potential impacts of climate-related disasters, including economic losses, health problems and environmental disruptions, will also affect – and be affected by – water.

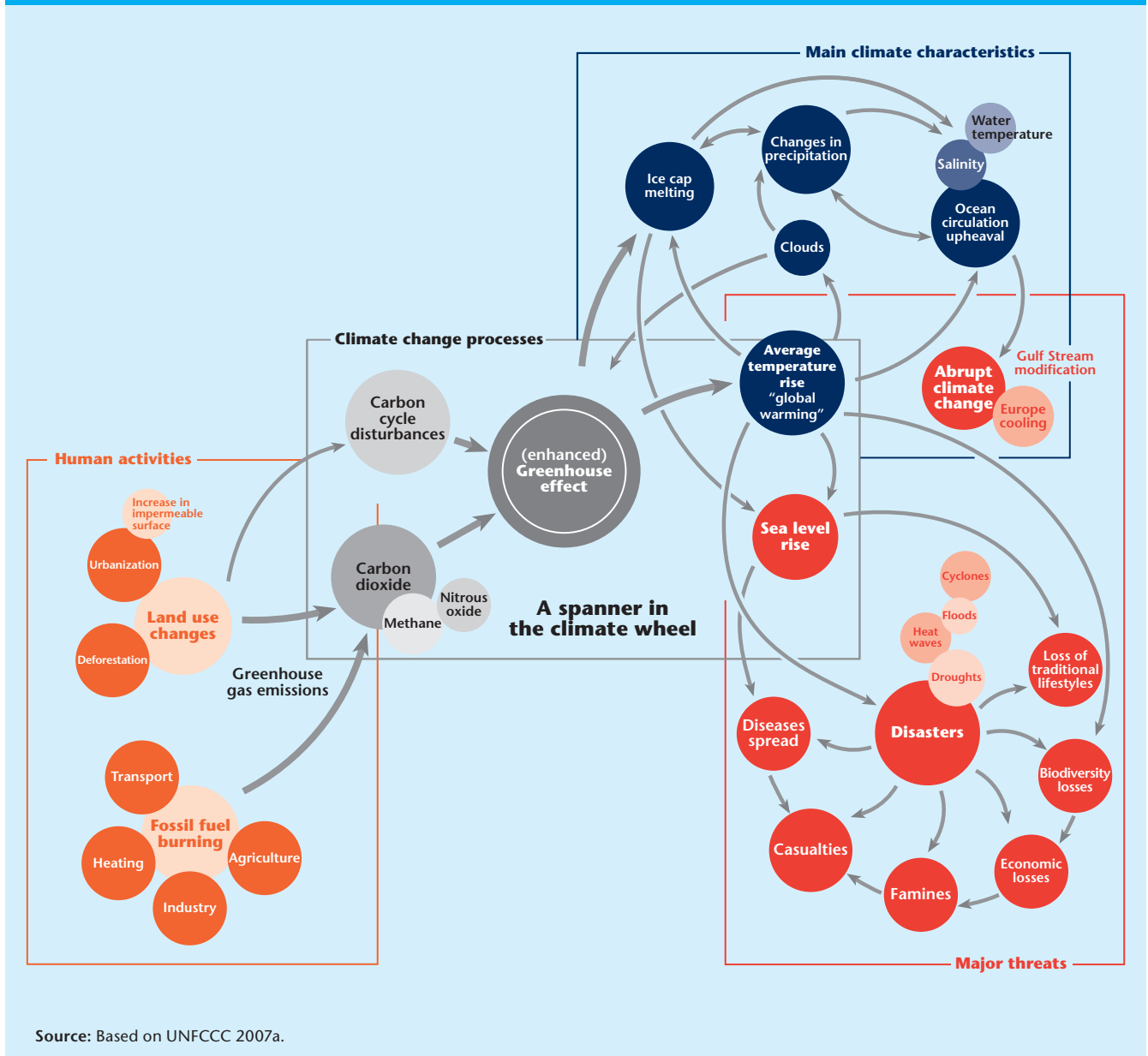
Climate change differs from the other drivers. It is the only supply-side driver, ultimately determining how much water we have; the other drivers are demand-side

drivers, influencing how much water we need. Climate change can directly affect the hydrologic cycle and, through it, the quantity and quality of water resources (see chapter 11). It can lower minimum flows in rivers, affecting water availability and quality for its flora and fauna and for drinking water intake, energy production (hydropower), thermal plant cooling and navigation. Anthropogenic climate change can also directly affect demand for water, when demand for crops increases in certain seasons, for instance (see chapter 7 for the implications of climate change on uncertainty in agriculture). The other drivers, by contrast, exert pressure on various water use sectors that, in turn, affect water resources.

Managing water has always been about managing naturally occurring variability. Climate change threatens to make this variability greater, shifting and intensifying the extremes, and introduces greater uncertainty in the quantity and quality of supply over the long term (see part 3). More subtly, climate change may alter the timing, magnitude and duration of precipitation events, which could pose problems



Figure 5.1 Climate change: processes, characteristics and threats



for the sustainability of water supplies and the continuity of treatment.

The decisions and policies put in place today for mitigation (such as reducing greenhouse gas emissions, applying clean technologies and protecting forests) and adaptation (such as expansion of rain-water storage and water conservation practices) can have profound consequences for water supply and demand both today and over the long term.<sup>1</sup> Climate change also adds to the uncertainty surrounding all the other drivers. Thus, examining climate change forces considerations of the interconnectedness of all the drivers. This chapter focuses on the pressures that climate change can exert on the other drivers and outlines a process for taking these

interlinking pressures into account in identifying scenarios, or 'possible futures'.

### The influence of climate change on the other drivers of change

The relationships between climate change and the other drivers are complex and interwoven. This section summarizes the influence of climate change on the other five major drivers: demographic processes, economic growth, social change, technological innovation and policies, laws and finance.

#### Demographic processes

The impacts of anthropogenic climate change, including increased water scarcity and flooding and accelerated glacial



**Weather-related disasters such as floods and droughts are undermining economic development in many of the world's least developed countries, causing human suffering and disrupting economic activities**

melting and sea level rise, have the potential to accelerate human migration. Drought, desertification and other forms of water scarcity are already estimated to affect as many as one-third of the world's people and are predicted to worsen.

The recent Intergovernmental Panel on Climate Change (IPCC) report notes that millions of people in densely populated low-lying coastal areas risk increasing exposure to flooding by storm surges over the 21st century.<sup>2</sup> The IPCC expects sea level rise to exacerbate floods, storm surges, erosion and other coastal hazards. Global warming can expand the endemic zones of water-related infectious diseases like dengue, malaria and schistosomiasis, making it increasingly difficult for people to remain in affected areas. Recurring floods or storm surges, if not managed effectively, could drive large numbers of people permanently from their homes. Current IPCC projections of rising temperatures and sea levels and increased intensity of droughts and storms suggest

that substantial population displacements will take place within the next 30-50 years, particularly in coastal zones. All of these climate change refugees will require shelter, water and sanitation services.

### Economic growth

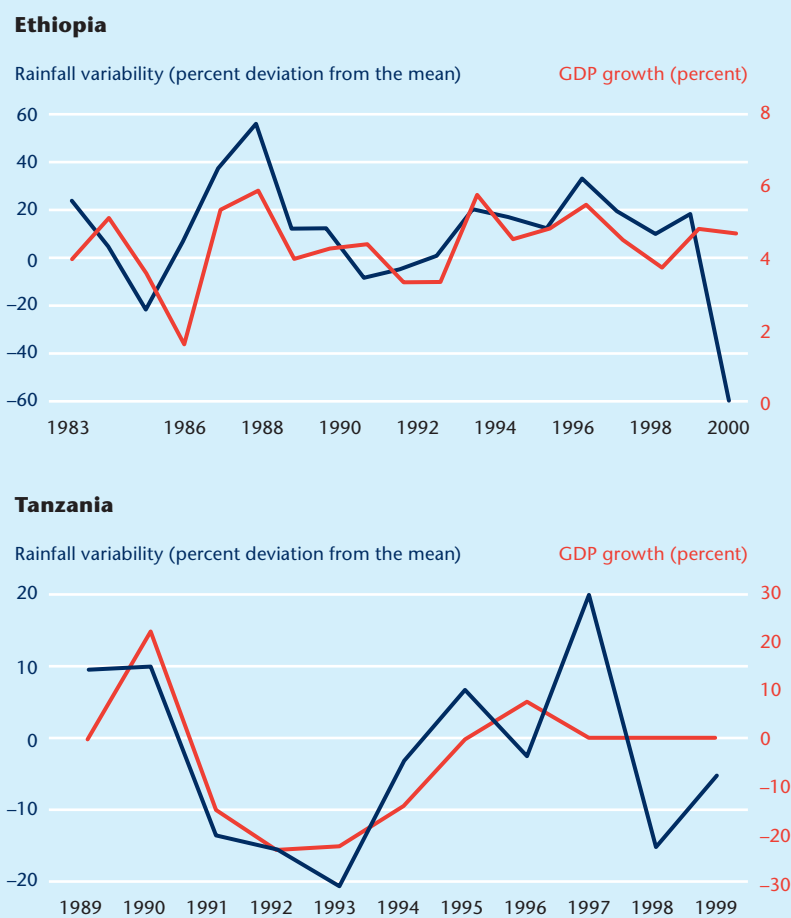
Climate change and its accompanying risks have direct and indirect effects on development and economic growth. Sea level rise, climate variability and weather extremes such as heat waves, floods and droughts are severe, direct threats to human life and property (see chapter 12). Tackling them requires mobilizing resources that may have to be reallocated from other investments. Their damage can substantially harm a country's gross domestic product (GDP). Economic performance is especially affected in developing countries because of their high and direct dependence on natural resources, notably rain-fed agriculture (see chapter 7), and their inadequate access to economic and technological resources.

Adverse climate conditions such as increased floods and droughts can also result in the underperformance of investments. Climate uncertainty and unpredictability can be powerful barriers to investments, and ultimately to economic growth, even in years when climate conditions are favourable. The changing climate also complicates infrastructure design and long-term investment planning. And internal and cross-border migration, driven by growing pressure on natural resources, can create tension among population groups and between countries.<sup>3</sup>

There is clear evidence of a relationship between climate variability and economic performance in countries in which agriculture is a large share of GDP, as in Ethiopia and Tanzania (figure 5.2). Evidence also suggests a strong relationship between economic development and vulnerability to disaster. Across developing countries losses associated with disasters are so large as to undermine development and poverty reduction goals. And yet climate risks are seldom adequately considered in infrastructure designs, agriculture investments and water management plans.

Weather-related disasters such as floods and droughts are undermining economic development in many of the world's least developed countries, causing human suffering (see table 12.1 in chapter 12) and disrupting economic activities (table 5.1). And substantial financial and other development resources are being diverted each year to post-disaster relief, emergency

**Figure 5.2 GDP growth tracks rainfall variability in Ethiopia (1983-2000) and Tanzania (1989-99)**



Source: Based on van Aalst, Hellmuth, and Ponzi 2007.



assistance, reconstruction and rehabilitation. Poorly managed climate risks also exact an indirect toll by discouraging private investment. With climate change and inadequate climate risk management, investors lack the reliable infrastructure, predictable human resources and stable markets needed to promote investment.

An estimated 40% of development investments are currently at risk, according to analyses by the Organisation for Economic Co-operation and Development (OECD).<sup>4</sup> These analyses indicate that while many development efforts contribute to reducing vulnerability to climate variability and change, climate risks are seldom explicitly factored into development projects and programmes. Similar issues affect sector and national development strategies.

The potential impacts of climate change on the global economy received international attention with the release of *The Stern Review* in 2006.<sup>5</sup> It concluded that by 2050 extreme weather could reduce global GDP by 1% and that, unabated, climate change could cost the world at least 5% in GDP each year. If even more dramatic predictions come to pass, the cost could rise to more than 20% of GDP. Such declines could in turn lead to an overall drop in official development assistance, exacerbating the struggle of poor people and countries to adapt and develop their water resources. Some other estimates of the costs of adapting to climate change are in box 5.1.

**Social change**

Unlike the more obvious effects of climate change on demographic processes or the global economy, the additional pressures that climate change is likely to exert on social change are often more subtle. Managing climate-related risk is a key enabler of development. Identifying and reducing the risks associated with climate-related hazards – including droughts, floods, cyclones, rising sea levels and extreme temperatures – can help to protect people, livelihoods and assets, thereby promoting the achievement of economic development goals.

Climate change and greater climate variability will increasingly affect the poorest and most marginalized groups, making them even more vulnerable to the impacts of climate change. Climate uncertainty – the inability to anticipate climate extremes – hurts investment and innovation and limits the success of other development interventions. In inhabited hazard-prone areas disasters and losses are inevitable

**Table 5.1 Economic impacts of flood and drought in Kenya, 1997-2000**

Impact area	Costs (\$ millions)	Share of total (percent)
<i>1997-98 El Niño flood impact</i>		
Transport infrastructure	777	89
Health sector	56	6
Water supply infrastructure	45	5
<b>Total flood impact</b>	<b>878</b>	
Share of GDP 1997-98 (percent)		11
<i>1998-2000 La Niña drought impacts</i>		
Industrial production	1,400	58
Hydropower	640	26
Agricultural production	240	10
Livestock	137	6
<b>Total drought impact</b>	<b>2,417</b>	
Share of GDP 1998-2000 (percent)		16

Source: World Bank 2004.

**Box 5.1 The cost of adapting to climate change**

Estimates of the costs of climate change impacts vary because they depend on future greenhouse gas emissions, mitigation measures and assumptions about anthropogenic climate change itself and about how effectively countries will adapt to it. The following are some estimates of the costs of adaptation for developing countries:

- World Bank estimates of the additional costs to adapt or climate-proof new investments range from \$9 to \$41 billion a year. And a recent update by the United Nations Development Programme put the mid-range of the costs of adaptation at about \$37 billion a year in 2015.
- The United Nations Framework Convention on Climate Change estimates additional investments for adaptation to climate change

at \$28-\$67 billion and as high as \$100 billion a year several decades from now. Estimates of the additional investments needed in water supply infrastructure in 2030 are \$11 billion, 85% of it in developing countries.

- Oxfam estimates the current costs of adaptation to climate change for all developing countries at more than \$50 billion a year.

While there is considerable debate about these estimates, they provide useful order-of-magnitude numbers for assessing resources available for adaptation. Current Global Environment Facility funds (about \$160 million) are several orders of magnitude too little to meet these projected needs.

Source: World Bank 2006; UNDP 2007; UNFCCC 2007b; Oxfam 2007.

unless societal exposure and vulnerability are reduced.

The most likely societal effects of climate change will come from changes in lifestyle and consumption patterns. Reflecting human needs and wants, changes in lifestyle and consumption patterns are among the most important drivers of change (see chapter 2). In emerging market economies rising standards of living are boosting demand for high-level goods and services, many with a large ecological and water



footprint. In the world's richest countries, meanwhile, growing awareness of climate change is slowly inducing people to alter their lifestyles and live in a more sustainable manner. Large cars are being replaced by smaller, more energy-efficient vehicles in some places, and governments are offering subsidies for purchasing energy-efficient appliances. But these changes alone are unlikely to substantially counteract the pressure from rising living standards in emerging market economies.

### Technological innovation

Climate change will be a major driver of technological innovation and transfer.<sup>6</sup> Massive amounts of new investments will be required over the next 30 years to meet the growing energy needs of developing countries. Investments in adaptation will be necessary to safeguard vulnerable groups and infrastructure.

The relationship between climate change mitigation measures and water can be reciprocal. Mitigation measures can adversely influence the quantity and condition of water resources and their management, while some water management policies and measures can increase greenhouse gas emissions and affect other sectoral mitigation measures. Thus, interventions in the water system might be counterproductive when evaluated in terms of mitigation of climate change.

For example, many developed countries are shifting energy production from thermal energy plants that burn fossil fuels and emit large quantities of greenhouse gases to 'clean' energy sources. Thus, significant increases in the development of hydroelectric installations, a source of clean electricity, could be anticipated as

the global community unites to combat climate change, although in many developed countries most of the 'best' sites for hydropower installations have already been developed (see map 7.6 in chapter 7). Some of the climate-related benefits of hydropower are illustrated in box 5.2.

However, there is evidence that hydroelectricity generation can also generate considerable amounts of greenhouse gases, which are released from sediment and decaying organic matter at the bottom waters of reservoirs.<sup>7</sup> Artificially flooded reservoirs of sufficient depth can experience anaerobic conditions as organic matter decomposes and, when the bottom waters are disturbed, emits large quantities of methane and other greenhouse gases. The problem arises most frequently in warmer climates, where reservoirs are prone to stratification and where there is year-round algal growth.

Biofuels, an alternative to fossil fuels in transport, are another means of reducing greenhouse gas emissions. Higher oil prices in recent years have made bioenergy more competitive. *World Energy Outlook 2006* projected an average rate of growth of bioenergy production of 7% a year.<sup>8</sup> By 2030 biofuels are expected to meet 4% of road-transport fuel demand worldwide, up from 1% today. But careful attention also must be given to minimizing negative externalities associated with producing bioenergy, such as upward pressure on food prices and the impact on food security.<sup>9</sup>

Developing countries will need to rely on technology development and transfer in mitigating and adapting to climate change. That will require removing obstacles to technology transfer and providing incentives for accelerating and scaling up transfers, along with cooperating on research and development (see chapter 3). According to the United Nations Framework Convention on Climate Change (UNFCCC), most technologies for adapting to climate change are already available in developing countries, and examples of successful implementation and operation abound, from coastal revetment to vaccination programmes.<sup>10</sup>

### Policies, laws and finance

Climate change can stress political governance structures by increasing management and budget requirements for public services to mitigate climate change or to cope with its impacts, including public health care (box 5.3), disaster risk reduction and

#### Box 5.2 Micro-hydro plants in Nepal are expected to provide electricity access to 142,000 households and to reduce greenhouse gas emissions

Nepal has vast hydro resources. And while only about 27% of rural households are connected to a power grid (the urban share is 90%), off-grid power generated by micro-hydro plants provides many rural households with electricity for lighting, milling and other needs. The generating capacity of these plants varies from 5 to 500 kilowatts.

Through a project supported by the World Bank, the United Nations Development Programme and the governments of Denmark and Norway,

micro-hydro plants are being installed for local communities by prequalified private companies that receive subsidies and technical assistance. Installation of micro-hydro plants will be phased in until 2011. The micro-hydro power plants, which qualify for emission reduction credits under the Clean Development Mechanism, will reduce greenhouse gas emissions by replacing diesel fuel used for lighting and milling.

Source: <http://go.worldbank.org/9G19LTLEH0>.



public security. As stress mounts, the resilience of already unstable social and political structures lessens, especially in countries with limited resources. At the international level pressures build on governance systems to combat climate change, mainly through the UNFCCC and growing public awareness.

Most efforts have focused on mitigation strategies, which are especially important for policies in energy (a major water use sector), international trade and transportation. In many countries climate change issues fall under the authority of the ministry for environment or natural resources. But as regional carbon trading markets emerge and as economies become ever more carbon-constrained, the ministries of finance and planning will need to become more directly involved.

Most governance structures today are too weak to tackle current water problems, much less prepare for emerging problems, including climate change. And there is still very little evidence about which types of governance responses work in which contexts and what their impacts are on water equity, efficiency and sustainability. Water reforms in most countries have not considered the implications of climate change or other major drivers of water use and the need for long-term planning.

Effective funding mechanisms are lacking for developing countries to support adaptation to climate change, which affects development at many levels. In Africa the impacts of climate change are expected to range from increased energy shortages, reduced agricultural production, worsening food security and malnutrition to the increasing spread of disease, more humanitarian emergencies, growing migratory pressures and increased risks of conflict over scarce land and water resources. Africa is least able to meet the costs of adapting to these impacts, yet it receives the least from current carbon finance mechanisms. Its governance structures and capacity are not ready for the intersectoral action that adaptation requires.<sup>11</sup>

Supporting developing country efforts to design adaptation strategies also requires better analysis. Information is needed at the local level, incorporating country-specific characteristics and sociocultural and economic conditions. At the macro-level information on both rich and poor countries is required to support international negotiations and to identify

### Box 5.3 Health and climate change

Climate change can affect health through multiple pathways, such as greater frequency and intensity of heat waves, fewer cold-related illnesses, increased floods and droughts, changes in the distribution of vector-borne diseases and effects on the risk of disasters and malnutrition. The overall balance of impacts on health is likely to be negative, and populations in low-income countries are likely to be particularly vulnerable to the adverse effects. However, many

of the projected impacts of climate change on health are avoidable. Climate change is expected to exacerbate some health problems rather than cause new diseases to emerge. Strengthening public health prevention strategies, including improving water supply and sanitation services and disease surveillance, would be an essential part of any effective response.

Source: Haines et al. 2006; Campbell-Lendrum, Corvelan, and Neira 2007.

the overall costs of adapting to climate change.

### Challenges for the impact of climate change on water resources and management

One of the most pressing challenges of climate change is addressing the vulnerability of human populations, particularly the poor, to the impacts of extreme hydrologic events, such as floods, storm surges and droughts. Over the longer term the effects of incremental climate change are likely to influence decisions about food security, energy security and land use, all with vital implications for water resources and management and environmental sustainability (see chapter 7). In this context climate change can intensify existing pressures, thereby increasing risk, vulnerability and uncertainty.

For water managers anthropogenic climate change poses a new set of challenges – because they can no longer plan, design and operate hydrologic systems based on historical statistics. Climate change means learning to manage under increased uncertainty. Climate change is a new risk to be taken into account in policy development, planning and operations at the global, basin, national, local and company levels. It calls for increasing use of ‘climate knowledge’ to better understand climate variability at different time scales, to assess the socioeconomic impacts observed in the past, to monitor current conditions of relevant environmental factors (climate, vegetation, water, diseases) and to provide the best possible information on future climate, from seasons to decades, for specific decisions and activities. Addressing the threats and opportunities of climate change and its impacts on water resources and supplies is vital for even the most remote rural areas as part of a broader developmental agenda.



**The water drivers interact and can have even more of an impact on future water resources collectively than they can individually**

Although water is an important component in most energy-generating processes, its role in climate change mitigation policy is minor. Where water and climate change are most strongly linked is in adaptation policy, which functions in highly dynamic hydrologic, social, economic and demographic contexts. For water adaptation measures to be effective, however, there must be complementary climate change mitigation measures outside the water sector.

Because climate variability and change affect all the major water drivers, adaptation measures are needed in all sectors. Over the long term adaptation means applying a long-term, climate-focused approach to existing policies and programmes. But because the poor are the most vulnerable and the least able to cope with change, it is particularly important to strengthen the link between adaptation to climate change and economic development – a difficult challenge. Over the shorter term the best approach might be to manage climate variability by prioritizing risk-reduction strategies and reinforcing the capacity of hydrometeorological services to provide information for development needs.

Each country will face its own challenges and must determine how to respond in the short, medium and long run. With multiple challenges but limited financial and natural resources and capacities, countries will need to make hard choices about water use and allocation.

There tends to be a push and pull effect between identifying adaptation needs based on a climate change rationale and anchoring response options in baseline development activities. This separation between climate adaptation and development is artificial. Governments need to design climate-smart development policies and programmes, in part by strengthening sectoral capacities.

### **Identifying possible futures: the need for scenarios**

Each of the water drivers is dynamic and continues to evolve, as do the direct and indirect pressures they exert on water resources. Thus, it is difficult to draw a comprehensive picture of the future by examining each driver independently. The drivers interact and can have even more of an impact on future water resources collectively than they can individually. Future scenarios that consider these interactions offer a more holistic picture.

Scenarios, which are sets of equally plausible futures, differ from forecasts, which are individual interpretations of a most probable future based on extrapolation of the best available information. Scenarios are not forecasts. Because the real world is so complex, forecasts are often wrong – especially those involving a time horizon of 20 years or more. Scenarios provide a means of looking beyond the water sector in search for an adequate causal understanding of different water issues.

Scenarios can contribute to several goals in the pursuit of sustainable water resources:

- *The need for a long-term view.* A long-term view of water for sustainable development requires taking into account the slow unfolding of some hydrologic, environmental and social processes and allowing time for waterworks investments and water mitigation schemes to yield results.
- *The need to make decisions in a context of high uncertainty.* Decision-makers in the water sector must often address water management issues against a background of rapidly changing environmental conditions and increasing uncertainty. The uncertainty results from both a limited understanding of human and ecological processes and the intrinsic indeterminism of complex dynamic systems. Further, water resources futures depend on future human choices, which are unknown.
- *The need to include non-quantifiable factors.* The world's water system includes and is influenced by many factors that are difficult to quantify (such as cultural and political variables and processes), as well as factors that can be quantified and modelled mathematically (such as hydrologic and climatological dynamics and economic factors). Qualitative scenario analyses can provide insight into these factors that simulation models cannot.
- *The need for integration and breadth.* Water resources must be viewed holistically, considering both their natural state and the need to balance competing demands – domestic, agricultural, industrial and environmental – to ensure sustainability. Decisions on land use can affect the availability and condition of water resources, while decisions about water resources can also affect the environment and land



use. Decisions about economic and social futures can affect hydrology and ecosystems. And decisions at the international, national and local levels are connected. Sustainable management of water resources requires systemic, integrated decision-making that recognizes the interdependence of decisions; scenarios are particularly helpful for this purpose.

- *The need for perspective.* Qualitative scenarios provide guidance, perspective and context for computer models and sectoral studies, while models and studies provide consistency and feasibility checks for some elements of water scenarios, as well as numerical estimates of the modelled variables. Further, global scenarios provide a context for scenarios on a smaller geographic scale (local, watershed, national or regional). Many important changes in a river basin are determined by factors from outside the study area.
- *The need to organize understanding for decision-making.* Decision-makers may have difficulty identifying the elements from different studies that are most relevant for their decisions. Scenarios are developed with decision-making in mind. They are constructed to focus attention on causal processes and decision points, the unfolding of alternatives and the branching points at which human actions can significantly affect the future.
- *The need for an arena for conversation among water stakeholders.* Scenarios provide common frameworks for mapping and highlighting critical concerns of diverse stakeholders and identifying alternatives – setting the stage for discussions, debates and negotiation.

Over the past decade several global scenarios have been developed for the water sector. One of the most comprehensive was the scenario work for the World Water Vision in 2000.<sup>12</sup> The Vision generated three scenarios: a technology, economics and private sector scenario in which private sector initiatives lead research and development and globalization drives economic growth, but the poorest countries are left behind; a values and lifestyles scenario in which sustainable development is a global priority, with emphasis on research and development in the poorest countries; and a business-as-usual scenario.

In 2006 the World Business Council for Sustainable Development (WBCSD) produced three scenarios focusing on the role of business and water.<sup>13</sup> Its three storylines focus on efficiency (more value per drop), security (meeting the basic needs of all) and interconnectivity (a ‘whole system’ approach; table 5.2). In another example using driver categories similar to those in this Report, the *Global Environment Outlook* (GEO4) report of 2007 generated four different scenarios: markets first, policy first, security first and sustainability first.<sup>14</sup>

Despite these recent endeavours, experience indicates that new global water scenarios are needed. Existing global water scenarios do not fully incorporate each of the drivers described in this chapter. The scenarios are either outdated (those of the World Water Vision) or partial, incomplete or sectoral (WBCSD, GEO4). In addition, the evolution of the drivers and the logic behind their storylines need to be examined and possibly redefined in view of developments both inside and outside the water sector since 2000. Finally, important new policy initiatives have emerged since the last world water scenarios, such as the adoption of the Millennium Development Goals.

### Challenges for summarizing the pressures of external drivers on water resources

Multiple external drivers exert pressures on water resources through changes in water demands and uses. Some of these pressures are summarized in the table at

**New global water scenarios are needed. Existing global water scenarios do not fully incorporate each of the drivers described in this chapter**

**Table 5.2 The three water scenarios of the World Business Council for Sustainable Development, to 2025**

Scenario	‘Hydro’	‘Rivers’	‘Ocean’
Water challenge	Efficiency (more drops for less and more value per drop)	Security (quantity and quality for all)	Interconnectivity (taking the whole system into account)
Business challenge	Innovation	Social license to operate	Business role in water governance
The five key story themes	<ul style="list-style-type: none"> <li>• Hard times in huge towns</li> <li>• Huge opportunities</li> <li>• High-stakes innovation</li> <li>• Hydro economy</li> <li>• Beyond legacy systems</li> </ul>	<ul style="list-style-type: none"> <li>• The security deficit</li> <li>• Two sides of the river</li> <li>• The trust deficit</li> <li>• Access and equity</li> <li>• Political reallocation – local solutions</li> </ul>	<ul style="list-style-type: none"> <li>• Unintended consequences</li> <li>• Global Fair Water Movement</li> <li>• The tipping point</li> <li>• Accountability tools</li> <li>• Networked global water governance</li> </ul>

Source: WBCSD 2006.



the beginning of part 2. The challenge is to get decision-makers inside and outside the water sector to adopt appropriate measures to reduce the negative pressures on water and increase the positive pressures.

Making this challenge more difficult are the links between drivers (as illustrated

by the pressures imposed by rising living standards), which involve demographic, social and economic factors but are also influenced by technology and governance. Generating a picture of this complex future would be greatly assisted by the development of a set of future scenarios.

## Notes

1. IPCC 2008.
2. Nicholls et al. 2007.
3. van Aalst, Hellmuth, and Ponzi 2007.
4. OECD 2005.
5. Stern 2006.
6. IPCC 2008.
7. Giles 2006.
8. IEA 2006
9. FAO 2008.
10. UNFCCC 2006.
11. van Aalst, Hellmuth, and Ponzi 2007.
12. Cosgrove and Rijsberman 2000.
13. WBCSD 2006.
14. UNEP 2007.

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