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dialogue on water and climate

Climate changes the water rules:

How water managers can cope with today's climate variability and tomorrow's climate change

dialogue on water and climate

The Dialogue on Water and Climate

International Steering Committee

- World Water Council and the 3rd World Water Forum
- Global Water Partnership (GWP)
- The World International Union for the Conservation of Nature (IUCN)
- International Water Association (IWA)
- Netherlands Water Partnership
- WMO and UNEP: Intergovernmental Panel on Climate Change (IPCC)
- International Federation of Red Cross and Red Crescent Societies
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- UNESCO
- The World Bank
- United Nations Development Programme (UNDP)
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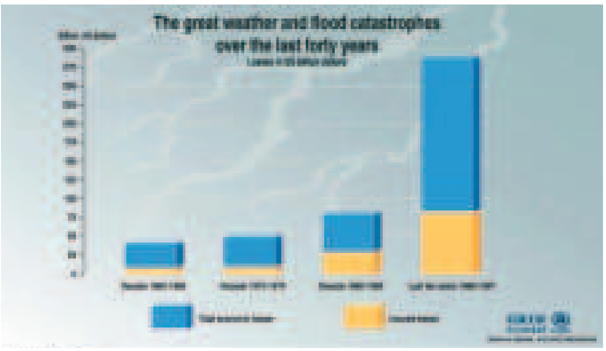
Weather hits the headlines . . .



Economic losses from weather-related disasters are rising fast

Statistics show that climate variation is getting more and more extreme. But the statistics are only confirming what people can see for themselves. Day after day, the world's media bring news of another weather emergency, costing millions of dollars in humanitarian relief. Below are just a few examples of Red Cross press releases from the last quarter of 2002. (http://www.ifrc.org/news/index.asp).

Caribbean hurricane season ends with floods in Costa Rica and Panama

12 December 2002

"Costa Rica's National Meteorological Institute said a month's worth of rain fell in one night on November 23-24.

The distribution of drinking water has collapsed in many areas, because wells have been contaminated by flood water".

Emergency assistance after Morocco hit by worst floods in 30 years

5 December 2002

"Twenty thousand people are in need of immediate assistance after heavy rains and floods hit western Morocco.

The flash floods, the worst in 30 years, killed at least 63 people in several provinces on Morocco's Atlantic coast. Most of the victims died when their houses, built of straw and mud bricks in dried-up river beds, were swept away".

Western Paraguay devastated by drought

17 October 2002

"The two-year drought has affected the western Paraguayan departments of Alto Paraguay, Boquerón and Canindeyu.

The "tajamares" drainage systems used for collecting water are now totally dry, while the cisterns used to store water are unhygienic and the water they contain not drinkable. To date 17 people have died of diseases related to drinking contaminated water, and there has been a marked increase in infectious diseases".

Albanian flood catastrophe

30 September 2002

"The rains began on 22 September and brought a repeat of the floods which swept much of Central Europe this summer. Neglected river defences, the reduced capacity of lowland drainage stations and power cuts that shut down pumps exacerbated the problem.

The floods in Albania are about more than water. Officially, a quarter of the 3.1 million population already lives below the poverty line, there are high levels of endemic unemployment and malnutrition is growing. Devastating floods washing out livelihoods are a dramatic episode in a worsening scenario".

Photos by courtesy of the International Federation of Red Cross and Red Crescent Societies.

Overview: A weather warning for the water world

Actions not excuses

For water resource planners, managers and ministers, this report is a wake-up call. A rapidly growing catalogue of storms, floods and droughts from all parts of the world makes climate variability a headline issue (see panel opposite). Extreme weather records are being broken every year and the resulting hydro-meteorological disasters claim thousands of lives, disrupt national economies and leave affected populations bemused and angry. People are looking for assurances and actions to combat the effects of extreme weather events, not for excuses about their rarity.

Development goals at risk

Behind the disaster statistics are climatic trends that pose serious challenges to the management of the world's water resources. In doing so, they also threaten the Millennium Development Goals of water and food security, poverty alleviation and sustainable development. Reservoir yields, river flows and lake storage volumes all have to be adjusted to take account of the risks of longer, drier dry seasons, shorter, more intense wet seasons and, in all probability, a remorselessly rising global temperature. This report provides compelling evidence (in Chapter 1) that climate variability is increasing all the time. There are still no certain links to long-term climate change, but the observed medium-term trends in annual rainfall and river flows and the projected increases in evaporation losses are enough on their own to call into question the historic hydrological calculations of water resources managers.

The Sahel example shown in the table is one of the most pronounced, but there are many examples around the world of climate-induced hydrological conditions moving outside the design assumptions of the water infrastructure. Typical strains on urban water systems include:

- Higher demands in hotter, drier seasons, when supply is at a minimum
- Floods far exceeding the design capacity of protection works
- High rainfall exceeding sewer capacities and leading to sewage overflow
- Less dilution of wastewater discharges by diminished river flows

In the rural areas, big fluctuations in annual river flows bring floods to some and droughts to others, ruining the livelihoods of farmers and calling into question past calculations of storage needs.

Already faced with formidable challenges of water scarcity and an anticipated increase in water demand of 25-50% in the next 25 years, water managers have shown little enthusiasm for factoring long-term climate predictions into their calculations. Now, as the evidence mounts, ignoring the problem is no longer an option. New attitudes are needed to prepare for and adapt to the effects of climate variability and the likely implications of climate change.

Country	Reduction in Precipitation (%)
Cameroon	16
Togo	16
Central African Rep.	17
Benin	19
Ghana	19
Nigeria	19
Guinea	20
Chad	20
Ivory Coast	21
Burkina Faso	22
Guinea Bissau	22
Mali	23
Senegal	25

River	Gauging Station	Reduction of Annual Flow (%)
Comoe	Aniassue	50
Chari	Ndjamena	51
Logone	Lai	39
Niger	Malanville	43
Niger	Niamey	34
Bani	Douna	70
Oueme	Sagon	42
Sassandra	Semien	36
Senegal	Bakel	50
Bakoye	Ouali	66
Black Volta	Dapola	41
Black Volta	Boromo	46
Oubangui	Bangui	30

The table of average precipitation and river flow changes in Sahelian countries over consecutive 20-year periods shows that the reductions are substantial and consistent. The figures compare average annual precipitation and river flows in the period 1970 to 1989 with those between 1950 and 1969.

The poor suffer most

Climate variability affects both developed and developing countries, and both need to adapt their water management practices to cope with its effects. In this report, there are examples of adaptive responses in the Murray-Darling basin in Australia, the Kisogawa basin in Japan, and the flood plains of the Rhine and Meuse in the Netherlands. Each faces substantial challenges, but the greatest challenges of all are undoubtedly in the developing countries. It is the poor who are hit first and hardest by the breakdown of infrastructure that usually accompanies droughts, floods and other extreme climatic events. Their suffering and their loss of livelihoods repeatedly set back poverty reduction goals. Whether it is floods in Mozambique or droughts in Northeast Brazil, it is the displaced communities and subsistence farmers who must start from scratch again and again to rebuild their shattered lives.

The framework for adapting to climate variation encourages self help and fosters local-level collaboration among organisations that can contribute to preparedness and mitigation strategies. That means establishing stakeholder groups that include community representatives, NGOs, government agencies and private sector companies, and using their inputs to formulate adaptation strategies.

Preparation pays

The potential rewards are high. During the 1990s alone, hundreds of thousands of lives and hundreds of billions of dollars were lost through weather-related disasters. There is growing evidence that precautionary designs, disaster preparedness, mitigation measures and adaptation of lifestyles can have a huge impact on these figures. The 1991 storm surge claimed 140,000 lives in the coastal belt of Bangladesh. Since then, the government built up disaster preparedness. The death toll in the similar 2001 storm was much lower at 200. In four drought-affected Indian States the building and restoration of rainwater harvesting structures has helped an estimated 20,000 villages to grow crops and maintain domestic water supplies. Community-based early warning systems in Guatemala have combined electronic monitoring devices with specially trained volunteers to reduce the death toll and impacts of flooding events in the Coyolate River basin. When Hurricane Michelle hit Cuba in November 2001, effective disaster planning ensured that 700,000 people were evacuated safely. There are many more examples in this report that can serve as models for those who have yet to recognise the benefits of adapting to climate variability. The Red Cross has estimated that every dollar spent on protection can save from four to ten dollars in relief. According to the Vietnam Red Cross, which has been directing a programme to protect the country's coastal inhabitants against frequent typhoons, "the planting and protection of 12,000 hectares of mangroves has cost around US$ 1.1 million, but has helped reduce the cost of dyke maintenance by US$ 7.3 million per year."

Adapting to climate variability will guard against climate change

Forecasts of climate change may remain debatable for some time; evidence of increased climate variability is incontestable, and the severity of that variability demands urgent responses from water managers. The reassuring aspect of this argument is that adaptation options for coping with climate variability now will also help to reduce the impact of climate change in the future. They include the conventional technological elements of water infrastructure, like storage reservoirs, boreholes, recharge wells and sand wells, but with an emphasis on techniques for boosting the yield of available resources (rainwater harvesting, water recycling/reuse, desalination). Adaptation benefits enormously from improved forecasting and climate modelling, and that means strengthening data gathering (many hydrological stations in developing countries have become defunct over the years through lack of investment). Risk sharing and access to credit for affected families are among the financial mechanisms that are being adapted to be responsive to floods and droughts. On a more structural level, modification of land-use patterns, crop selection and tillage practices can be considered.

Dialogue on Water and Climate

Part of the problem for water managers is that there has been little interchange with the climate community. Because their designs have been based on historic records and their management on hydrological observation stations, there has not been a perceived need to seek medium and long-term climate forecasts. Meteorologists are getting better at forecasting extreme weather with longer warning times. Growing knowledge of the processes involved in phenomena like El Niño, also means that seasonal climate variability can be anticipated with more confidence in affected regions. However, because there has been little interchange with the water sector, the climatologists are often not being made aware of the kind of forecasts and modelling tools needed to serve the water managers. Their forecasting and warning systems are designed largely for aiding emergency planning and relief operations.

The Dialogue on Water and Climate (DWC) was launched in September 2001 with the aims of bringing together water managers and climate specialists, raising awareness of climate implications, and transferring knowledge and experiences. DWC initiated some 18 stakeholder dialogues at national, regional and river basin levels. These individual Dialogues have been successful in addressing the implications of climate variation and climate change in their own situations. Indeed, many of the illustrative examples in this report have been drawn from the Dialogues. The results of each Dialogue are summarised in Chapter 4's Yellow Pages. The Dialogue concept is being recommended as a useful model for countries to adapt to their own circumstances in responding to the challenges of water management in a changing climate.

Who pays for adaptation?

It is easy to argue that the developed world has an obligation to pay for the impacts of climate change purely on the basis that it is the industrialised countries that are primarily to blame for greenhouse gases. There are even more compelling arguments, based on common interests. Every weather-related disaster carries a huge human and financial cost. The need for humanitarian relief is going to get greater and greater, as hydro-meteorological disasters grow in frequency and intensity. Pre-emptive funding for adaptation has to be an appealing way of reducing the relief costs of individual extreme climatic events. Reducing the vulnerability of threatened communities and the ecosystems on which they depend offers an immediate and substantial payback for donor governments and relief agencies. It also lessens the risk that hydro-meteorological disasters will repeatedly wash away hard-won progress towards develomental targets like the Millennium Development Goals.

"Hot Spots" and vulnerability

The impacts of our varying climate are felt in all parts of the world, but the severity of the impacts and the vulnerability of people and ecosystems differs enormously from place to place. Some "hot spots" are obvious. Small islands and low-lying coastal areas will be devastated by rising sea level; megacities with illegal shantytowns in floodplains face huge losses from flooding and storms; and countries already struggling to produce enough food for growing populations are particularly susceptible to seasonal fluctuations in rainfall. There are other generalisations that can be made about vulnerability to climate change, but right now determination of vulnerability at the local level is more intuitive than scientific. It is the coping capacity of local communities and governments that has to be evaluated alongside weather-related risks. For the communities themselves, the awareness of increasing threats to their fragile livelihoods is enough to motivate adaptive action. For support agencies seeking to prioritise, it is not easy to compare the vulnerability of subsistence farmers in drought-threatened Kenya with that of landless squatters in the floodplains of Dhaka.

As we show in Chapter 3, techniques are evolving for combining different susceptibilities to climate change with proxy indicators of adaptive capacity at local level. In the meantime, stakeholders are using their own perceptions of vulnerability to drive local agendas for action in many parts of the world.

The adaptation agenda

Based on the results of the 18 Dialogues and analysis of a wide range of experiences around the world, DWC has compiled a compendium of "Coping options" at global, regional and national levels. Tabulated in Chapter 4, the compendium offers a comprehensive "menu" from which water managers and their governments can find the best ways to integrate climate variability and climate change into their development policies.

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Foreword

"Change in the earth's climate and its adverse effects are a common concern of humankind."

Plan of Implementation
World Summit on Sustainable Development

Over the past ten years there has been much debate about meeting the targets for greenhouse gas emissions outlined in the Kyoto Protocol. Although all efforts to reduce greenhouse gases should be strengthened and supported, the reality is that for the next several decades, atmospheric concentrations will remain at levels much higher than any time over the last 400,000 years. Climate change is much more likely to get worse before it gets better.

But why should we, in the water sector, be concerned with climate change? After all, our priorities are dealing with the present water crisis - about providing safe water and improved sanitation for billions of the world's poorest people; about supplying enough water to grow the food to feed an ever increasing global population; and about leaving enough water in the natural environment to preserve ecosystems and conserve biodiversity. Indeed, climate change is not the primary concern of water managers and this report does not propose that it should be.

What this report does say is that we are not doing as well as we should be to manage water in response to to-day's climate variability - and the consequent droughts and floods. It argues that if we learn to manage these phenomena of to-day better we will develop the resilience that will help us to manage more serious results of climate change to-morrow.

One of the most important impacts of global warming is what climate scientists refer to as "an intensification of the hydrological cycle". Loosely translated, this means shorter periods of more intense rainfall, and longer warmer dry periods. Already, extreme weather records are broken every year. Hydrological disasters have claimed thousands of lives and disrupted national and regional economies. Years of economic development often have been wiped out by a single event. Water managers have started having to deal with record fluctuations in water availability, from critically dropping reservoir levels to overflowing sewerage and drainage systems. Climate change need not be an immediate concern for water managers, but current climate variability should be.

Most countries are not ready to cope adequately with today's climate variability, and the poorest countries are the most vulnerable. The climate community has knowledge to share with water managers. They can offer tools and knowledge that can help us to manage today's problems. They could help us more if the water community worked more closely with them to explain what we need to know and what kind of tools would be most useful to us.

This report provides a wealth of information about climate change and variability. It also offers a first ever compendium of specific adaptation strategies for water managers and decision-makers to draw upon and a first overview of international support initiatives on water and climate.

Unfortunately, the bulk of international funding related to climate change has gone towards mitigation (i.e. reducing greenhouse gas emissions) and to relief efforts. While these remain important and should be maintained, greater investment in coping and adaptation capacity is sorely needed. Investing in adaptation capacity today will not only save lives and livelihoods, it will save money spent on relief efforts.

After only two years of effort, the Dialogue on Water and Climate has succeeded in raising awareness of the issue among both water managers and climate-water scientists. It is my hope that this process and discussion of this report at the 3rd World Water Forum will lead to commitments to joint actions to reduce the vulnerability of so many of the world's poor to the vagaries of climate.

William J. Cosgrove
Chairman
International Steering Committee
Dialogue on Water and Climate

Contents

Chapter 1: The Evidence

The hydrological cycle continuously replenishes the world's water resources and is the foundation of life on earth. Now we find that a combination of natural and human activities is having a disturbing influence on the cycle. Dramatically changing weather patterns mean that the replenishing water arrives as intense rainfall, overwhelming flood defences and escaping to the ocean before it can be stored to quench thirsts, irrigate crops, sustain ecosystems, drive hydroelectric turbines or meet the needs of industry.

Distinguishing long-term climate change (CC) from short/medium-term climate variability (CV) is the first step in understanding and tackling our vulnerability to extreme weather events like typhoons, floods and droughts. In Chapter 1, graphs, charts and examples illustrate the way that weather patterns are changing.

As our understanding of El Niño, La Niña and other climate-varying phenomena gets better, can we find better ways to cope with the resulting weather extremes? What will the trends towards more extreme weather mean for today's and tomorrow's water managers?

Forecasting next week's weather and next season's climate is a crucial part of disaster preparedness and long-term planning. How good are the forecasts and the modelling systems, and do they really meet the needs of water managers? What we find is that scientists feel more confident about predicting what the world's climate might be like in 50 or 100 years time for different development scenarios than they do about forecasting when the next drought might hit Kenya. Which is not the way that Kenya's long-suffering farmers would prefer it.

Chapter 2: Impacts

Even without the impacts of climate change, water managers face prodigious challenges in meeting sustainable development goals. Growing populations need affordable food, water and energy. Industrial development demands a growing share of water resources and contaminates those same resources with its untreated wastes. Nature is at the back of the queue, but preserving enough flows to sustain aquatic ecosystems is vital for human survival and to preserve biodiversity. By 2025, the global demand for freshwater is expected to rise by 25% or more, but we are still contaminating the available supplies at an accelerating rate.

The drinking water supply and sanitation sector has laudable targets: safe water and sanitation for all by 2025, with the intermediate Millennium goal of halving the proportion of people lacking those basic services by 2015. Considering that in the year 2000 more than a billion people had no safe water supply and some 2.4 billions lacked hygienic sanitation facilities, a huge collective effort is needed even to approach the objectives. Factoring in climatic extremes adds to the challenges, but it is vital if progress is not to be continually wiped out by hydrometeorological disasters. When drinking water wells and latrines are flooded or falling groundwater tables leave hand pumps dry, there are disease epidemics, deaths and "environmental refugees", and years of investments by people and governments are rendered worthless.

Agriculture is the biggest water consumer and climate change will not alter that. What may change though is the balance of food production, with the developed countries producing a greater share of rising food demands and developing countries dining on imported "virtual water".

As water gets scarcer, balancing the needs of people and those of nature becomes even harder. Nature is adaptable and resilient, but shrinking lakes and declining fisheries are just two of the indicators that there are limits to our maltreatment of her.

When La Niña brings drought and declining river flows, it is not just food production that suffers. Loss of hydropower damages industry, the power companies, and ultimately people’s jobs. The threats from climate variability and climate change are many and varied.

Chapter 3: Assessing vulnerability

It is in the shantytowns and rural villages of the Third World that floods and droughts strike hardest and deepest. Vulnerability to the vagaries of climate depends not only on location, but, crucially, on the capacity of the victims to cope with the impacts of extreme weather.

So, where are the people most at risk from the effects of climate variability and climate change? It is not an easy question to answer. How can we compare the hazards facing the inhabitants of a small island as the sea level rises with those that confront African farmers from prolonged drought? And is the sea a greater threat to Bahrain or the Comoros Islands?

Climate change predictions provide part of the answer. Human development indicators can help to indicate the likely coping capacity, and there are other social, geographic and environmental parameters that have to be taken into account. Combining all these variables in mathematical models is allowing specialists to make comparisons that development agencies can use to determine the most critical regions or "hot spots".

The techniques are still evolving, but some interesting conclusions are starting to emerge. Climate changes are likely to mean 12% less cereal production in sub-Saharan Africa, even though eight of the region's countries will actually produce more under many of the climate scenarios tested. The answer to the islands question is that the Comoros are and will remain the most vulnerable to sea level rise. However, if the "Climate Vulnerability Index" method of comparison is to be believed (it is still experimental), by 2030, population growth and a worsening environmental situation will see Bahrain closing in fast as the small islands hot spot.

Where people are vulnerable, so are development goals. Look at the predicted effects of Hurricane Mitch on Nicaragua's previously encouraging progress in bringing down poverty. By 2008, it could mean as many as quarter of a million less people removed from extreme poverty, unless there is more outside support.

Chapter 4: Coping options

Adaptation is the key word for communities, local authorities and governments trying to cope with a worsening climate. While rich nations battle over reducing greenhouse gases, rich and poor have to deal with the present impacts and plan for worse to come.

Water managers are working to new rules, as river flows and reservoir levels respond to changing rainfall patterns. Early warning systems, hazard maps and disaster preparedness strategies are being drawn up. Banks and insurance companies are finding new ways to share risks and repair costs. Climate is on the development agenda.

Evidence that things are starting to happen comes from 18 "Dialogues" – multi-stakeholder groups that have come together to assess their own vulnerability (or their country's, or their region's) to climatic extremes. They started in 2002 as part of a collective effort to bring water and climate specialists together to tackle the escalating human and financial costs of weather-related disasters.

They have moved fast, and action plans are being drawn up in every continent, based on a mixture of self-help, knowledge sharing, and policy changes at all levels. The collective experiences of the dialogues, supplemented with expert views from all around the world, have led to the publication here of the first "Coping Compendium". Recognised to be incomplete, it nevertheless offers a broad menu of potential actions that will help threatened communities and their leaders to "adapt" to the climate challenge.

Chapter 4's "Yellow Pages" contain summaries of each of the 18 Dialogues, giving a worldwide perspective of climate-and-water issues.

Chapter 5: External support

It is clear that the biggest burden from climate-related disasters falls on developing countries. That is where the investments in early warning systems, more reservoirs, better flood defences and refuge shelters need to be made.

Most developing countries will need technical and financial support, and they have a powerful case to make. For the industrialised nations, still spewing greenhouse gases into the atmosphere, it is a case of "the polluter pays". It is also a case of protecting past and future investments. Damages from floods and droughts cost billions of dollars in relief and years of development progress. Investing in precautionary adaptation is a comparative bargain.

Chapter 5 has more Yellow Pages, this time listing international organisations able to offer knowledge, data and capacity building support. It also has a guide to the institutional minefield facing countries seeking financial support for "adaptation".

The momentum generated by the Dialogues is to continue in the form of a new Water and Climate Alliance, with an ambitious programme of awareness raising and progressing National Adaptation Programmes of Action (NAPAs).

Chapter 6: Recommendations and conclusions

Work will continue. The Water-and-Climate ball is rolling and there is a strong commitment to keep it going. This wrap-up chapter contains a ten-point action agenda for countries, river basin authorities, regional organisations and the international development community.

Climate changes the water rules

Chapter 1: The Evidence

Chapter 1: The Evidence

1.1 Water management and climate

Water is inextricably linked with food security, human health and environmental protection. Rapid population growth, increasing urbanisation, industrialisation and pollution threaten the sustainability of our water resources. Natural climate variability and human-induced climate change add to those threats, particularly in developing countries where the impacts are potentially great and the capacity to cope is weakest. Hydrometeorological disasters such as floods and droughts have major effects on food supplies, health, economic and environmental losses, and social upheaval. Economic losses from natural disasters, including floods and droughts, increased three-fold between the 1960s and the 1980s[1].

Drought is a normal recurring feature of climate. It has many causes, often synergistic in nature. Droughts occur in virtually every climatic zone, but their characteristics vary significantly from region to region. Floods too have multiple causes. They may simply be generated by torrential rains from tropical and extra-tropical cyclones. Though excessive rainfall alone can cause flooding, the most severe riverine floods usually involve a combination of meteorological and hydrological factors. These can include, for example, an earlier unusual sequence of rainfall events (that could have been predicted from short-lead seasonal climate forecasts), saturated soil conditions and high river flows prior to the critical rainfall event(s). New understanding of climate and its variations on seasonal and inter-annual scales, together with a growing ability to predict seasonal phenomena like El Niño, provide new means of reducing our vulnerability and improving our capacity to cope with weather extremes.

Water managers have to deal with a host of interlinked issues: supply; quality; allocation; distribution; equity with respect to present and future generations; resource vulnerability and reliability; sustainable use; biological diversity; and ecological integrity. For many water managers in developing countries, vulnerability to future climate changes may seem to be a far-away problem. Certainly, many argue for focussing on current pressing issues related to population growth, economic underdevelopment and lack of investment in water infrastructure, rather than on climate change. To some water managers, dealing with natural climate variability and climate-related hazards such as droughts and floods has always been a part of their routine concerns. For them, taking climate change into account does not mean adding any new magic tricks to their present practices for coping with climate extremes, except perhaps in some regions with high vulnerability to climate change, like small islands or low-lying coastal zones. What they do have to recognise, as we will see later in this chapter, is that climate variability is increasing fast and future weather is likely to be more extreme more frequently.

Also, in many countries the good practices of adapting to climate variability are not yet in place. Effective management of climate risks calls for a holistic approach linking technological, social and economic development with the protection of natural ecosystems and with dependable projections of future climatic conditions. There is a need to mobilise expertise across several disciplines to provide the knowledge and methods necessary to assess the climate risk connected with rural and urban water management, and to develop adaptive strategies that can respond to emerging climate fluctuations and help to reduce adverse impacts. The process involves making connections between climate prediction, climate-related hazards, climate change, and the planning, design, operation, maintenance, and rehabilitation of water-related infrastructure.

Establishing a balance between consumptive use, environmental needs, subsidiary functions such as flood control, and the ill-defined costs and benefits of climatic impacts on fisheries, aquatic ecosystems, scenery and recreation, is technically complex and subject to a high level of uncertainty. It requires difficult decisions involving the interests of various sectors of the economy, the community and the environment. By taking a proactive approach, water managers can pre-empt and avoid water crises whenever possible and devise effective responses to crises when they occur. To date, most water managers have adopted a static rather than adaptive approach to setting operating policies. This risk-averse behaviour is often encouraged by the constraints imposed by political and institutional arrangements and societal expectations. However, increasing demand for water from finite sources will progressively lead to decisions that are more responsive to current and forecast climatic conditions and involve a higher degree of uncertainty and risk. (see section 1.5.6).

1.2 Defining climate variability and climate change

Our climate has never been stable for any extended period of time. Natural external causes of climate variability include variations in the amount of energy emitted by the Sun, changes in the distance between the Earth and the Sun, and the presence of volcanic pollution in the upper atmosphere. Internal variations of the climate system also produce fluctuations, through the feedback processes that connect various components of the climate system. These variations arise when the more rapidly varying atmospheric conditions "force" the slow components of the system like internal variations in the ocean, cryosphere, or biosphere. They are intensified by coupling of components of the system that would not have such an effect on an individual basis. The El Niño–Southern Oscillation phenomenon (see section 1.3.2) is one of the best examples of internal variability.

[1] http://freshwater.unep.net/index.cfm? issue=water_flood_drought

Paleoclimatic records (derived from deep cores taken from polar ice caps, and from fossilised tree rings) indicate that climate varies at every frequency – seasonal to millennial and beyond, and that a shift between dramatically different climate states can occur in a matter of years and/or decades. Figure 1.1 compares the concentrations of two major greenhouse gases, CO_2 (blue curve) and CH_4 (green curve), and the inferred temperature record from the ice core taken from the Russian Vostok station in East Antarctica in January 1998. Over the last 400,000 years, changes in temperature (red curve) run parallel with changes in the atmospheric concentrations of the greenhouse gases. It is only in the last 10,000 years that temperatures have not varied by more than 1° degree Celsius in a century.

Since the industrial revolution and expansion of agriculture around 200 years ago, emissions of

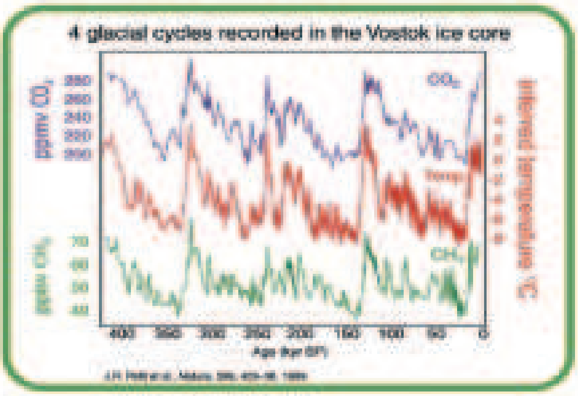


Figure 1.1 *Paleoclimatic records from the Vostok ice core, showing natural climate variability over the last 400 000 years. Changes in temperature (red curve) run parallel with changes in the atmospheric concentrations of the greenhouse gases carbon dioxide (blue curve, maximum levels of about 280 parts per million by volume- ppmv) and methane (green curve, maximum levels of about 80 parts per billion by volume- ppbv). After Petit et al, 1999. Nature, 399, 429-436.*

greenhouse gases and aerosols due to human activities have progressively altered the composition of the atmosphere (Figure 1.2). The Intergovernmental Panel on Climate Change (IPCC) notes an increasing body of observations giving a collective picture of a warming world and other changes in the climate system, and new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activities (IPCC, 2001). Figure 1.3 shows that the global average near-surface temperature has increased about 0.6°C since 1900. The rate and duration of warming in the 20th century has been much greater than in any of the previous nine centuries, and it is likely that the 1990s have been the warmest decade and 1998 the warmest year of the previous millennium. Another key finding is that sea level has risen on average by 1-2 mm per year.

Other pieces of evidence reported by IPCC (2001) include: temperatures have risen during the past four decades in the lowest 8km of the atmosphere; snow cover and ice extent have decreased; and ocean heat content has increased. Instrumental records of land surface precipitation (rain, hail and snow) continue to

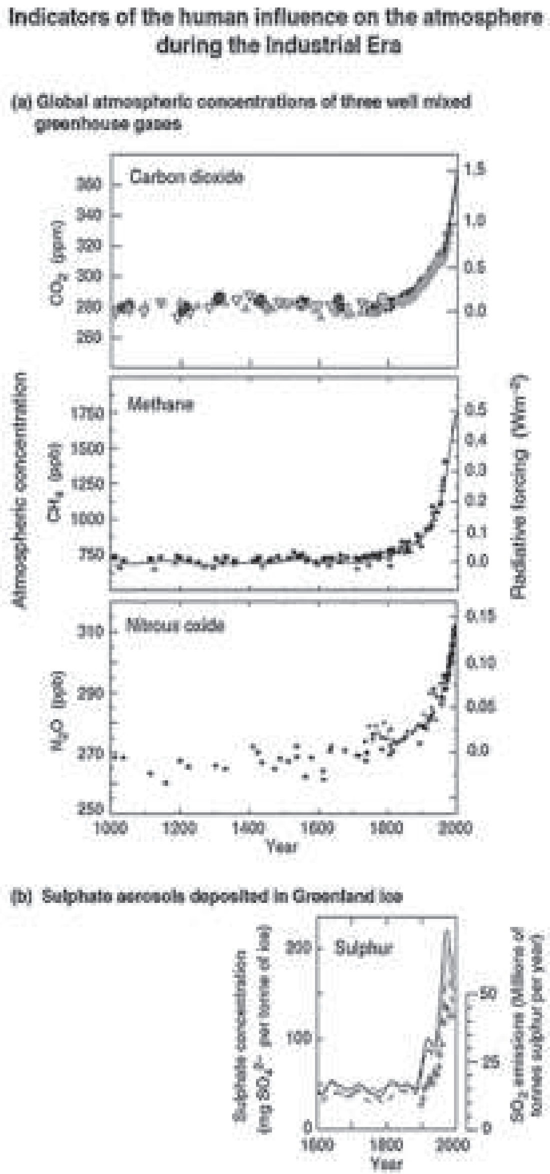


Figure 1.2 *Long records of past changes in atmospheric composition provide the context for the influence of anthropogenic emissions (IPCC, 2001). Comparison with the Figure 1.1. shows that our Planet has not experienced the present level of atmospheric CO_2 concentration (about 370 ppmv) for at least the last 400,000 years.*

show an increase of 0.5 to 1% per decade over much of mid and high latitudes of the Northern Hemisphere. In regions where the total precipitation has increased, there have been even more pronounced increases in heavy and extreme precipitation events. Moreover, increases in intense precipitation have been documented even in those regions where the total precipitation has decreased or remained constant. The changes in average annual precipitation have a cumulative effect on the sustainability of water resources; changes in storm intensities are more immediate, as the growing number of weather-related disasters shows only too well.

Throughout this report, we will distinguish between the terms *weather, climate, climate variability* and *climate change*. ***Weather*** refers to the day-to-day changes of the atmosphere. We experience it as wet or dry, warm or cold, windy or calm conditions. ***Climate*** is defined as the average of the weather over periods of longer than a

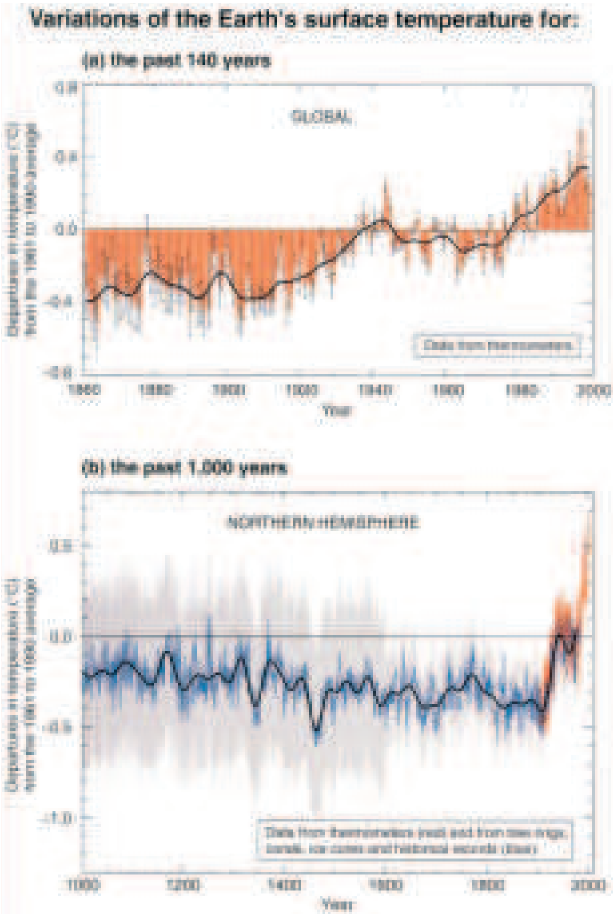


Figure 1.3 *Variations of the Earth's surface temperature over the last 140 years and the last millennium (IPCC, 2001)*

month (e.g., a season, a year, a decade, 30 years, and so on). ***Climate variability*** can be defined as the range of values that the climate at a particular location can take over time. As explained already, climate variability is an inherent feature of the natural climate system. However, we recognise that climate variability and climatic extremes may get exacerbated as a result of global warming (IPCC, 2001).

The United Nations Framework Convention on Climate Change (UNFCCC) defines ***climate change*** as a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods. In this report, we adopt the UNFCCC approach and restrict our use of the term climate change to projected future conditions of climate under various greenhouse gas emission scenarios (see section 1.5).

1.3 Climate variability: phenomena and consequences

1.3.1. The Importance of climate extremes

Extreme weather and climate events have received increased attention over the past decade, largely as a result of the exponentially-increasing losses that have been associated with them (Figure 1.4). Yearly economic losses from large events have increased ten-fold between the 1950s and 1990s. These losses largely reflect an increase in the vulnerability of society as a whole to extreme events (Kunkel et al., 1999). In many cases this increased vulnerability has not been matched by an appropriate increase in adaptive capacity. Part of the observed upward trend in losses is linked to socio-economic factors, such as population growth, expansion into and population concentration in flood prone areas, increasing wealth, as well as land use and river channel changes. However, these factors alone cannot explain the observed growth in economic losses; part of the losses can be linked to climatic factors, such as more intense storms, floods and droughts.

The World Bank's Water Resources Sector Strategy quotes examples of impacts of climate variability on economic performance. The drought in Zimbabwe in the early 1990s was associated with an 11% decline in GDP; the floods of 1999 in Mozambique led to a 23% reduction in GDP, and a drought in Brazil in 2000 halved projected economic growth. The scale of these losses highlights the need for water planners and managers to have a better understanding of the mechanisms of climate variability and their relationships with hydrological extremes such as floods and droughts.

Box 1.1 Anthropogenic climate change

The presence of so-called 'greenhouse gases' (e.g. carbon dioxide, methane, oxides of nitrogen and ozone) in the atmosphere retains heat and thus keeps the Earth's temperature higher than it would otherwise be. They all occur naturally, but their atmospheric concentrations have been altered significantly by human activity. Industrial processes also create other greenhouse gases, not previously present in the atmosphere, and their concentrations are increasing as well. The global annual emission of carbon dioxide from burning fossil fuel and other industrial processes is estimated to have increased from about 0.1 Gigatonnes of carbon (GtC) in 1860 to almost 10 GtC by the end of the 20th century. Over the same period, the atmospheric concentration of carbon dioxide has increased from about 280 parts per million by volume (ppmv) to about 369 ppmv and the global temperature of the Earth has increased by about 0.6° C. The most recent assessment of the Intergovernmental Panel on Climate Change (IPCC, 2001) is that, globally averaged, the surface temperature of the Earth is going to increase by between 1.4°C and 5.8°C over the period 1990 to 2100 as a result of human activities. Over the same period, an associated rise in global mean sea level of between 9 and 88 cm is projected. The 1992 United Nations Framework Convention on Climate Change (UNFCCC), including its Kyoto Protocol, is aimed at stabilizing human-induced greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous interference with the climate system.

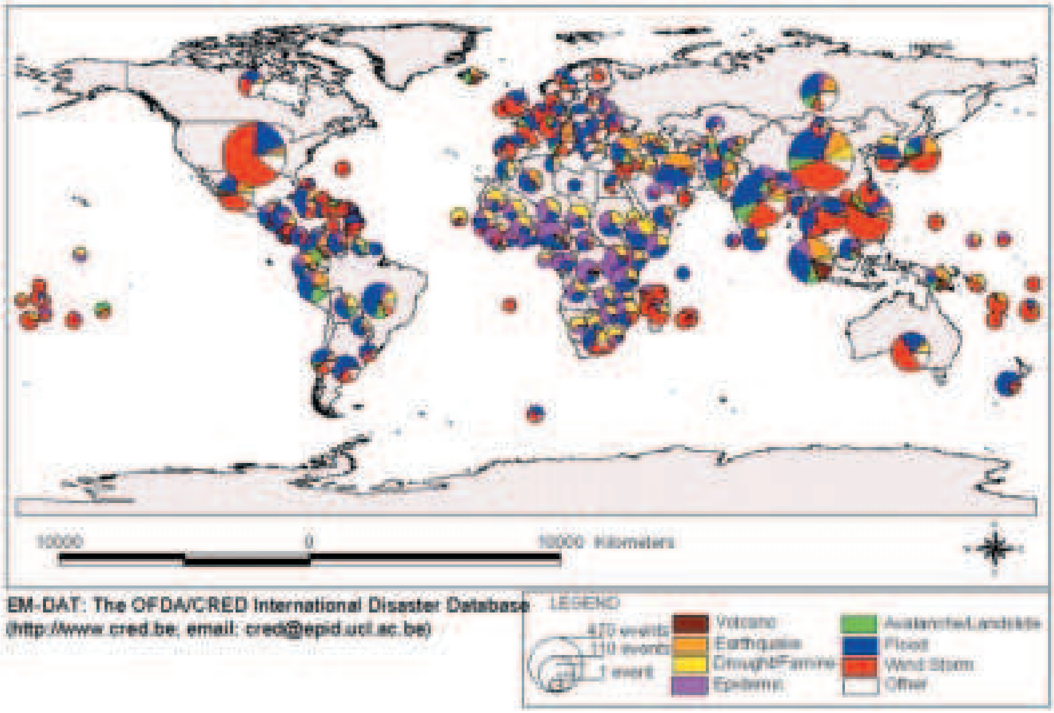


Figure 1.4 *Distribution of natural disasters, by country and type of phenomena .(Source: CRED, 2002)*

It is difficult to quantify the impacts of human activity on climatic extremes. Lack of long-term climate data suitable for analysis of extremes is the biggest obstacle to quantifying how extreme events have changed over the 20th century, either world-wide or on a regional basis (Easterling et al., 1999). However, recent changes in climate variability certainly seem to have adversely affected flood and drought hazards in several regions and this tendency is likely to continue (see section 1.5).

1.3.2 El Niño–Southern Oscillation (ENSO)

Largest source of natural variability in the global climate

There are a number of recognised large-scale climate phenomena, including: El Niño–Southern Oscillation (ENSO), North Atlantic Oscillation (NAO), Pacific Decadal Oscillation (PDO), and the Indian Ocean Dipole (IDO). At present, only climate forecasts based on the modelling of ENSO give any long-lead prediction accuracy. ENSO is one of the largest sources of natural variability in the global climate system. It is an anomalous large-scale ocean-atmosphere system associated with an irregular cycle of warming and cooling of sea surface temperatures (SSTs) in the tropical Pacific Ocean. The oceanic warming and cooling is accompanied by a 'seesaw' shift in surface air pressure between Asian and eastern Pacific regions (the 'Southern Oscillation').

The ENSO cycle has a time scale of from two to seven years and consists of three phases: El Niño (warm phase); La Niña (cold phase), and neutral periods. The long term behaviour of ENSO is poorly understood. A variety of indices are used to characterise ENSO because it affects so many components of the atmosphere-ocean climate system. The two main indices are the Southern Oscillation Index (SOI) and the Niño 3 index.

There was an apparent upward shift in the temperature of the tropical Pacific around 1976, which appeared to continue until at least 1998. During this period ENSO events were more frequent, intense or persistent. The behaviour of ENSO in the 1990s seems unusual compared with that of previous decades. Several weak to moderate El Niño events occurred with no intervening La Niña events during the period 1990 to 1995. This was found by some studies to be statistically very rare (IPCC, 2001).

In neutral periods, the Pacific Ocean is always poised on the brink of change and is easily influenced by the internal variability of the climate system. The trade winds blow towards the west across the tropical Pacific Ocean and pile up warm surface water in the western Pacific. This accumulation of warm water heats the air in contact with it. The warm air rises, lifting tonnes of moisture that condense in the atmosphere forming massive cloud banks that bring rain. Cool SSTs occur off the coast of South America due to an upwelling of cold water from deeper levels in the Ocean, and the eastern Pacific is relatively dry.

ENSO and the hydrological cycle

The extremes of the ENSO cycle are partly responsible for large climate variability year-on-year in many countries and regions. In Latin America, for example, ENSO is blamed for a large part of interannual climate variability. Table 1.1 lists El Niño and La Niña impacts

Box 1.2 El Niño and La Niña

El Niño is the name given to a Pacific basin-wide increase in both sea-surface temperatures in the central and/or eastern equatorial Pacific Ocean and sea level atmospheric pressure in the western Pacific. Typically, it leads to: drought conditions in Indonesia, eastern and northern Australia, South Africa, and northern South America; floods in northern Peru and Ecuador; a poor Indian monsoon; and increased rainfall in the southern region of the United States. Normally, El Niños begin early in the year and peak between the following November – January. An El Niño episode usually lasts from 14 to 22 months, but can be much shorter or longer. Recent El Niño events occurred in 1997, 1994, 1991, 1987, and 1982.

La Niña is characterised by stronger than normal (easterly) trade winds over the Pacific Ocean, and extensive cooling of the central and eastern Pacific Ocean. The cooler than normal eastern Pacific Ocean often results in low rainfall and sometimes drought in parts of South America, Central America and the United States, while rainfall in Indonesia and Australia is usually enhanced. La Niña usually lasts 9 to 12 months, but may persist for two years. It will not always follow an El Niño: since 1975, La Niñas have been only half as frequent as El Niños. Recent La Niñas occurred in 2000, 1999, 1998, 1996, and 1988.

on climatic and hydrologic variables for several Latin American countries and subregions. At decadal scales, multiple climate records throughout the region consistently exhibit a shift in the mean during the mid-1970s. This shift is evident in the climatic and hydrologic records for other regions too (see, e.g., IOCI, 2001).

Many studies have found reasonably strong relationships between streamflow variability and ENSO. Figure 1.5 shows distributions of the September to November inflows into the Wyangala Dam (New South Wales, Australia) for 1894 to 1996, sorted into categories according to values of the SOI in the preceding June to August period. The capacity of the Dam is 1,220 gigalitres (GL), a gigalitre being equivalent to a million cubic metres. The median inflow during La Niña events (SOI greater than +5) is about 230 GL and the 90th percentile is about 900 GL. The median during El Niño events (SOI less than –5) is only about 60 GL and the 90th percentile is less than 500 GL. The largest inflows are associated with La Niña events, and the smallest are associated largely with El Niño events and neutral conditions (SOI between –5 and +5).

Subregion or Country	Climatic/Hydrological Variable El Niño	La Niña
Argentina (Pampas)	Increase in precipitation during November-January	Decrease in precipitation during October-December
Chile and central western Argentina	Increase in runoff	Negative rainfall anomalies
Colombia	Decrease in precipitation, soil moisture and river streamflow	Heavier precipitation and floods
Northern Amazonia and northeast Brazil	Decrease in precipitation during rainy season (severe drought in NE Brazil)	Increase in precipitation, higher runoff

***Table 1.1** Examples of ENSO impacts on several Latin American countries and subregions (adapted from Mata and Campos, 2001)*

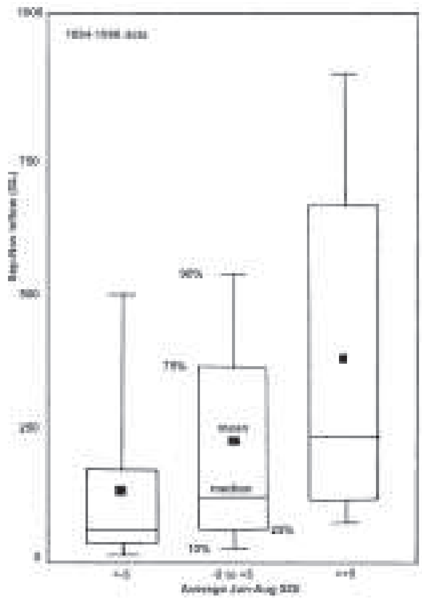


***Figure 1.5** September to November inflows into Wyangala Dam (Australia), sorted by values of the SOI in the preceding June to August period. Dots represent mean (average) inflow, top and bottom edges of the boxes the 10th and 75th percentiles, horizontal bar within each box the median, and the horizontal bars at the ends of the whiskers the 10th and 90th percentiles. (Source: http://iri.columbia.edu/climate/ ENSO/societal/example/ ChiewPlot.html)*

1.3.3 Floods

The hazards and benefits of floods

For millennia, humans have settled in floodplains in order to till fertile soils, use the flat terrain for settlements, gain easy and safe access to water and use rivers for transport. Riverine floods are natural phenomena; they have always occurred, and people have tried to benefit from them to whatever extent possible.

In recent decades though, humans have become more exposed to flood risk. Different pressures have combined to increase population densities in flood-prone areas. In particular, informal settlement has occurred in endangered zones around megacities in developing countries as people migrate towards the economically-developed cities. The hope of overcoming poverty drives the poor to migrate, frequently into places where effective flood protection is not assured. Thus floods have had increasingly detrimental and disruptive effects on, inter alia: human health (through diseases such as diarrhoea or leptospirosis in flooded areas); settlements and infrastructure; coastal areas; financial services (including insurance and reinsurance); transport; water supply; agriculture; and ecosystems.

Riverine floods have affected huge numbers of people in recent years – on average more than 100 million people per year. From 1990 to 1996 there were six major floods throughout the world in which the number of fatalities exceeded 1,000 and 22 floods with losses exceeding US$1 billion each. According to the Red Cross, floods in the period from 1971 to 1995 affected more than 1.5 billion people worldwide. This total includes 318,000 killed and over 81 million made homeless (IFRCRCS, 1997). The highest material losses were recorded in China during the 1996 and 1998 floods: about US$ 30 and 26.5 billion respectively. Although the majority of recent disastrous floods have occurred in Asian countries, few countries of the world are free of flood danger (see Table 1.2 and Box 1.3).

In February 2000, torrential late summer rains of return periods up to 200 years in places fell over parts of southeastern Africa (Smithers et al., 2001). The combination of two cyclonic systems in rapid succession and high levels of soil moisture from a wet early summer resulted in extraordinary flooding. Mozambique was affected most severely, but parts of other countries such as South Africa, Zambia, Zimbabwe, Botswana, Swaziland and Madagascar also suffered. Mozambique experienced its largest known flood. In February 2001,

Location	Duration (days)	Affected Region (km²)	Damages (USD/km²)
Central and South America			
Argentina and Chile	21	424 000	85 714
Brazil (central)	2	780 000	8 974
Brazil (west)	2	2 250	ni
Chile	12	166 900	190
Ecuador	54	52 930	ni
Peru	11	333 200	ni
Uruguay	30	187 500	ni
Venezuela (west)	11	224 900	13
Other			
Europe (central)	18	252 300	79 270
China (north west)	10	252 000	1 587
Russia (south)	12	224 600	1 945
Trinidad	15	880	3 750

Table 1.2 *Information on selected floods for the year 2002 (after Mata, 2003 data from Dartmouth Observation Laboratory)*

Box 1.3 The Mozambique floods of 2000 and 2001

The damage in Mozambique's 2000 flood was catastrophic: whole villages were covered by water, entire crops were destroyed, arable land was rendered unusable for the next three years, people sought refuge on roofs and tree tops. Whole sections of main roads were washed away, isolating many towns and villages, including the capital city, Maputo. The disaster left 700 people dead and half a million homeless. According to the UN World Food Programme, Mozambique lost at least a third of the staple maize crop and 80% of its cattle. A quarter of the country's commercial agriculture was damaged. The 2001 flood disaster carried away thousands more homes and inundated vast areas of farmland. At least 400,000 people were affected, with more than 40 people killed and 77,000 rendered homeless.

Mozambique once again faced a flood disaster, while still suffering from the effects of previous year's devastating floods.

Floods occur all over the world, even in arid regions (e.g. Yemen, Egypt, Tunisia). It may be counter-intuitive, but in dry areas more people die from the effects of floods than from lack of water, as the dryness is a normal state to which humans have adapted, while floods strike unprepared populations suddenly. Contrary to public perception, the occurrence of a large flood does not mean that it will be a long time before a flood of similar size will occur again in the same place.

". . . in dry areas more people die from the effects of floods than from lack of water."

For example, in December 1993 and the beginning of 1995 the Rhine River at Cologne experienced two floods that were similar in magnitude to the 100-year flood. Experience with recent floods leads to reductions in the damages caused by subsequent floods. In North Korea, disastrous floods in the summer of 1995 caused 68 deaths and US$15 billion total losses. In the summer of 1996 another flood, extending also to South Korea, caused 67 deaths and US$1.7 billion in material losses. But the memory and benefits can fade very quickly.

Not all floods are bad

Floods are the life blood of ecosystems in floodplains and deltas. Periodic flooding ensures that these wetland ecosystems supply important products (arable land, fisheries, livestock grazing), functions (groundwater recharge, nutrient cycling) and attributes (biodiversity) that have contributed to the economic, social and environmental security of rural communities for many centuries. Floods are also important for fish migration, riparian vegetation and sediment transport. Recently too, it has been more widely recognised that reductions in the frequency and magnitude of flooding caused by dams alter conditions for ecosystems and may degrade the services that nature provides for the benefit of humans. In response, the release of managed floods has been recommended by the World Commission on Dams (2000) and agreed as best practice as part of dam management by the World Bank (Acreman, 2002).

Do floods exhibit increasing trends?

It is evident that more floods are occurring and flood damages are rising in many parts of the world. There is also a change in the seasonality of floods. This is due, in part, to earlier peak flows following milder winters, and to a more persistent El Niño state. Berz (2001) examined inter-decadal variability of major flood disasters, where disasters are understood to be floods in which the ability of the region to help itself is distinctly overtaxed, making international or interregional assistance necessary. Based on data for the period 1950 to 1998, Berz contends that the number of major flood disasters world-wide has grown considerably and consistently in the past decades: six cases in the 1950s; seven in the 1960s; eight in the 1970s; 18 in the 1980s; and 26 in the 1990s. Pielke and Downton (2000) linked the rates of change in flood

Box 1.4 Expert opinions about the great flooding in Central Europe during August 2002.

(1) *Vaclav Baca (Povodi Vltavy, Czech state company that managed waterworks on the Vltava):* "It simply rained a lot". "You won't hear me say it is a sign of global warming"

(2) *Time Magazine, page 20 (August 26, 2002)* "Last week's weather does not fit the pattern suggested by global warming, which predicts wetter winters and drier summer as temperatures rise."Time Magazine (same issue): "However, others are not sure. If climate change is taking place, then researchers would expect more frequent bouts of unexpected and severe storms."

(3) *Michael Coughlan (Director, Climate Programme, WMO, Geneva)* "It is a case of one swallow does not make a summer….." "If you were to start to see more events like this then you might begin to say we are seeing global warming in action."

(4) *Russian scientist (unidentified)* "last week's wild weather is not unusual for the [flooded] region and is unrelated to global warming"

(5) *Bernhard Pelikan (Hydrologist, Institute for Water Economy, Vienna)* "The flooding in Austria was especially severe because of deforestation, intensive agriculture and heavy settlement around the river plains". However, he admitted the heavy rain.

(6) *Klement Tockner* (Aquatic Ecologist, Swiss Federal Institute of Technology, Zurich) "With heavy rainfalls, the problems with most rivers is that they are dammed in, so they rise instead of widening" He mentioned the case of the Friuli-Venezia Giulia region of Italy — "The river often floods due to heavy rainfall, it rarely rises more than 2 m above its average level because it is flanked on either side by meadows and forests that absorb excess water. In contrast, the Danube used to be surrounded by 26,000 km^2 of meadows that acted as a buffer zone. Now only 6,000 km^2 of meadows remain. Last week the Danube rose 6 m above its normal level in some places." Tockner argues that flood protection through natural meadows and forest would be more effective in the long run than apparent gains through agriculture and industry.

(7) *Michael Hulme (Director, Tyndall Centre for Climate Change Research, University of East Anglia)* "The brutal reality is that it takes a major flooding event to galvanise societies and government to take actions …. This certainly happened in Britain two years ago [when the country endured widespread flooding during the wettest autumn on record], and I suspect it will now happen in Central Europe."

(8) *Manfred Stock (deputy Director, Potsdam Institute for Climate Impact Research)* "Many regions will see an increase in extreme weather, and we will have to adjust to massive changes in our living conditions."

Box 1.5 Droughts and water supply in northeast Brazil

Northeast Brazil has a semi-arid climate, with strong spatial and temporal variations of rainfall. Water scarcity is a major constraint on agricultural production, quality of life and development of that region. The region has been struck by 18 to 20 droughts per century since the 17th century. The population, especially the poor, has been directly affected by the lack of drinking water, food and work. According to some estimates, nearly half of the population of an estimated total of 1.7 million died in the drought-related famine of 1877-1879. Nowadays, the existence of governmental assistance and emergency programmes prevent starvation and reduce migration (Magalhaes et al., 1988). However, during the extreme dry year of 1983, there were still a significant number of drought-related fatalities. The economy continues to suffer considerably during drought years, especially the production of subsistence crops such as beans and manioc. These crops were almost totally destroyed during the extreme drought of 1983, when the total GNP of that region declined 'only' by about 16%.

With an increasing population and the likelihood of even greater rainfall variability resulting from climatic change, scarcity of water resources is increasingly constraining development in the region. Efficient and sustainable use and management of water resources is imperative. This implies management of water storage both in small dams (to improve the water availability for the local subsistence farmers) and in large dams, combined with long-distance water diversions for water supply to urban centres (e.g. Recife or Fortaleza) and regions with a very pronounced water deficit. Assessment of water availability and sustainable use are key issues in this context.

characteristics with socio-economic indicators in the USA for the period 1932 to 1997.
They found that the total annual flood damage, adjusted for inflation, has grown at an average rate of 2.9% per year. This is a stronger growth than that of population (+1.26%) and tangible wealth per capita in inflation-adjusted dollars (+1.85%).

Milly et al. (2002) investigated the changes in risk of floods with discharges exceeding 100-year levels from 29 basins larger than 200,000 km^2 (the 100-yr flood is commonly used in flood risk assessment and the design of major structures). The period of record for the basins was at least 30 years. Predictably, the 100-year flood was exceeded 21 times in the observational record of 2066 station-years. The significant point though is the degree to which flood events were concentrated in the latter half of the record. Half of the observations were made before 1953, but 16 of the flood events occurred after 1953. This increase is statistically significant.

It would be a gross over-simplification to state that floods have exhibited growing trends everywhere. Signals in some river-flow data that have been ascribed to global warming have not been confirmed by research elsewhere. The time series of flood data reflect complex responses due to other non-climatic factors, such as changes in catchment use or manipulation of water within the channel (e.g. dams, abstractions, canalisation). The behaviour of such series is not necessarily in tune with expectations from climate-change-related prognoses alone.

As a result of the increasing frequency and magnitude of extreme events worldwide, debate on attribution of these extremes to climate change has entered the public arena, but the controversies surrounding attribution are large. A small collection of "expert opinions" after the extreme flooding in August 2002 in Central Europe is given in Box 1.4.

1.3.4 Droughts

The hazard posed by drought

Droughts have both direct and indirect consequences for human livelihoods. A direct consequence is crop loss, which can cause starvation if alternative food sources are not available. Indirectly, water shortages contribute to the spread of disease, because people lack water for basic hygiene. If a

Box 1.6 Recurrent droughts in Canada

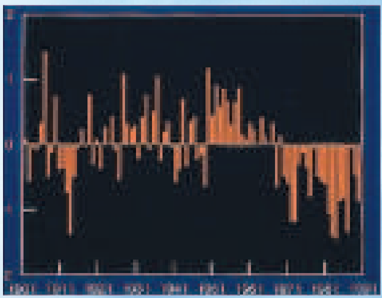
Since the 1930s, drought has occurred quite frequently in Canada. While the effects have been less dramatic compared with the North American "dust bowl" in the Thirties, the impacts continue to take a toll on Canadian society, with immediate and long-term effects on the economy and the environment.

The drought of 2001 was one of the worst droughts on record in Canada, affecting water sensitive sectors from British Columbia to the Atlantic provinces. Record low precipitation was recorded in some areas while portions of the prairies experienced their second consecutive year of near-record low precipitation. Soil moisture is depleted over much of the western prairies and winter snowfall has remained well below normal. Forty-five percent of the livestock farms were facing water shortages. Both agriculture yields and quality suffered throughout the country, with overall yields down between 50 and 60 percent of normal.

The winter of 2001-2002 has been a dry one in many parts of the country, raising fears of further drought problems in the upcoming growing season

(Brian Abrahamson, Agriculture and Agrifood Canada, PFRA)

Box 1.7 Droughts in the Sahel



The Sahel is a zone with high variations in average annual rainfall over decades. During the past century, several severe droughts have occurred, including an extraordinarily long-lasting drought, without precedence in the observed climatological record. Significant reductions in precipitation (see inset figure from Sehmi and Kundzewicz, 1997) and, as a result, reducing river flows, have been observed in the past decades over large areas in Africa. For example, since 1970 the mean annual discharge of the Niger River at Koulikoro has nearly halved from its levels in the 1960s. The river virtually dried up at Niamey in 1984 and 1985. The Senegal River at Bakel almost stopped flowing in 1974 and 1982, and again in 1984 and 1985. The mean annual discharge of the Nile has fallen from the long-term mean of $84km^3$ (1900-1954) to $72km^3$ in the decade 1977-1987, and the mean flow between 1984 and 1987 was as low as $52km^3$, with an absolute minimum of $42km^3$ observed in 1984 (Howell and Allan, 1990).

Accepting uncertainty concerning human impact on the environment, Mainguet (1994) proposes a variety of small and specific actions for the gradual rehabilitation of the Sahel environment: reduction of arable land to those areas with reliable irrigation possibilities; widespread use of solar energy as an alternative to burning wood; and restrictions placed on the drilling of wells for water supply. However, the demographic growth in the Sahel region will render any measures to combat drought and desertification extremely difficult. The high vulnerability to climate change is likely to aggravate social and environmental problems (Sokona and Denton, 2001). Awareness building is therefore urgently needed as an area of bilateral and international aid programmes.

drought persists, people are often forced to migrate. Drought can also inhibit regional development, by contributing to a cycle of poverty.

Droughts are more difficult to define in quantitative terms than floods. Obviously a drought occurs because of a lack of available water. But this can be through a lack of precipitation per se, a lack of available soil moisture for crops, surface flows falling below a critical threshold, reduced water levels in reservoirs, or reduced levels of groundwater. The impact of drought on a region depends on the adaptive capacity of the humans or the ecosystems to cope. Droughts have been known to cause severe crop losses not only in semi-arid regions, but also in well-watered countries such as the Netherlands, Bangladesh and Japan (see Bangladesh and Nagoya Dialogue reports in Chapter 4).

Semi-arid and arid regions generally display strong climate variability temporally and spatially, and they frequently face extremely dry situations. Future climate changes are expected to change the frequency, severity and geographical location of droughts. However, socio-economic changes such as population growth, increasing demand for water per capita, or loss of traditional knowledge and practices to adapt to drought or urbanisation, can exacerbate the vulnerability of particular populations to drought.

Box 1.8 Drought in the Horn of Africa

In the Horn of Africa, there is a complex state of emergency in which drought interplays with political instability. Long-lasting civil wars in Eritrea, Ethiopia and Somalia hamper the establishment of reliable political systems and the development of stable economies. A prolonged drought threatens those countries' main grain harvest. Large parts of the vital sorghum crop frequently fail due to drought, and insects damage much of the remainder. Drought-displaced populations in urban centres of Somalia and Ethiopia live under conditions of poor sanitation and hygiene, which have resulted in serious health problems and child deaths. Repatriation of war-affected Eritrean refugees from Sudan causes enormous problems in handling the large number of returnees. The lack of water, massive land erosion and the presence of landmines, with an alarming increase in mine incidents, hinder the re-establishment of agricultural activities and long-term sustained food production. A large proportion of the population, which produced a major part of the countries' food supplies in former times, now depends on emergency food delivered by international donor programmes.

What do we know about recent hydrological droughts?

Countries and regions that have been severely impacted by drought in the 20th century include Afghanistan, Ethiopia, Kenya, Pakistan, India, the Middle East, and Northeast Brazil (Box 1.5). The African continent, especially the Sahel and southern and central Africa, has been exposed more than any other region of the world to the risk of recurrent drought (Box 1.7). The IPCC (2001) points out that the causes of African drought are numerous and vary over regions, seasons, and years. Local droughts occur every year; continental drought crises appear to occur once (or more recently twice) every decade. Major droughts tend to be connected to ENSO anomalies. Wolde-Georgis (1997) show that drought and associated famines in Ethiopia have a remarkably close association with ENSO events.

Sahelian populations have been living with drought for thousands of years. Nomadic and semi-nomadic lifestyles are a traditional way of coping with high rainfall variability. In recent decades, drought impacts in the Sahel have been exacerbated by the agricultural expansion that took place during the wet decade of the 1950s. When climatic conditions deteriorated in the late 1960s and 1970s, many of these new agricultural areas became unviable, as did a nomadic lifestyle in the even drier areas to the north. The result was famine and conflict, as crops failed and people competed for resources. The deterioration of soil and vegetation by overgrazing, with rising potentials for increased wind and water erosion, is widely cited as a cause of environmental degradation in the Sahel. However, there is no evidence that such processes have caused a systematic deterioration of the Sahelian environment. While population pressure may result in the overexploitation of resources, there is also evidence that it encourages agricultural innovation that can lead to sustainable land management.

Extreme drought may cause considerable environmental, economic and social losses in western countries. It is estimated that the 1988 drought in the USA may have caused direct agricultural loss of US$13 billion. The 1998-1999 drought affected the eastern regions of the USA and the grain growing period in 1999 was the driest on record for four states. The drought of 2001 was one of the worst droughts on record in Canada, affecting water sensitive sectors from west to east (Box 1.6).

There is evidence that some droughts are caused predominantly by mismanagement of water resources rather than by climate variability. An extreme example comes from the Aral Sea basin where, due to excessive water withdrawals from the tributaries Syr Darya and Amu Darya, the Aral Sea has shrunk dramatically. However, there has also been a more widespread loss of moisture: in the latter half of the 20th century there has been increased drying of the land during summer in some areas, increasing the risk of drought (see Aral Sea Dialogue Report in Chapter 4).

1.3.5 Other extreme climate phenomena

There are a number of weather and climate extremes other than floods and droughts. They include: tropical cyclones (hurricanes, typhoons) and associated storm surges; wind storms; hail storms; heatwaves and cold spells; avalanches and landslides; and wildfires (see Figure 1.4). These extreme events occur on a variety of spatial and temporal scales. For example, tornadoes last a few minutes and extend over a few hundred metres whereas the effects of tropical cyclones last from hours to days and their impacts extend over hundreds of kilometres. The impacts of these extremes include loss of lives and livelihoods, contaminated food and water supplies, homelessness, and environmental degradation.

Hurricanes are among the most serious natural disasters and their impacts affect virtually every component of the water sector. Storm surge is a large mass of water often 100 to 200km wide that sweeps across the coastline near where a hurricane makes land fall. The surge of high water topped by waves is devastating. A storm tide is the combination of the storm surge and the astronomical tide. If the storm surge arrives at high tide, the water height will be even greater. For example, the hurricane "Camille" in 1969 produced a 7m storm tide in Mississippi, and in 1992, hurricane "Andrew" produced a 5m storm tide in south Florida. Winds of more than 130km/h can occur in hurricanes. Sometimes, hurricanes and tropical storms are accompanied by tornadoes.

Perhaps the most serious impact resulting from hurricanes is inland freshwater flooding. All tropical cyclones produce torrential rains, which can trigger landslides and mud slides, especially in mountainous regions. Flash flooding, a rapid rise in water levels, can occur quickly due to intense rainfall, while the long term flooding can persist for several days after the storm.

Box 1.9 Recent examples of weather-related disasters other than floods and drought (WMO, 2002)

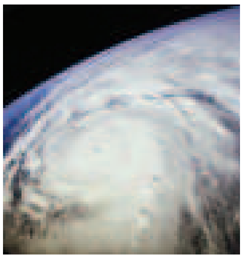
Cold spells: In Mongolia in January 2001, a blizzard with wind gusts of more than 100 km/h killed 12 herders and contributed to the deaths of 467,000 animals.

Hail storms: Storms in Munich, Germany (1984), Dallas-Fort Worth, USA (1995) and Sydney, Australia (1999) each caused damage costing more than US$500 million. Yearly, worldwide losses to agriculture are typically more US$200 million.

Heatwaves: During a severe heatwave in Shanghai in August 1998, the average death rate increased by 300%. The number of homicides committed increased by 139% during a heatwave in New York in 1966.

Tornadoes: In northern India and Bangladesh, over 400 people have been killed in each of three severe tornadoes since 1989.

Tropical cyclones: In 1999, a tropical cyclone struck the Indian State of Orissa, causing 40,000 fatalities. The cyclone swept inland with wind speeds of 300 km/h, and generated a seven-metre tidal surge that caused devastation to a distance of 20 km inland.



Left: a satellite photo of a tropical cyclone (http://www1.msfc.nasa.gov/newsroom/camex/photos/sts106-704-063_m.jpg)

Right, a tornado in New South Wales, Australia, (http://australiasevereweather.com/photography/photos/2001/0129mb04.jpg}

1.4 Predicting climate variability

1.4.1 How predictable is our climate?

Modelling the dynamics of the coupled atmosphere-ocean is sensitive to small changes in the data required to start a forecast. The errors and uncertainty inherent in these data are amplified throughout the period of the forecast. It is becoming common practice to repeat a forecast many times using "perturbed" initial conditions and multiple numerical prediction models (computer programs that use mathematical equations to represent natural processes). The resulting 'ensemble' provides the basis for probabilistic forecasts that attempt to overcome model and data uncertainty.

Scientists have incorporated our understanding of El Niños into numerical prediction models. These models are fed with information from observations of wind speeds, ocean currents, sea level, and the depth of the thermoclime (a transition layer of water in the ocean that separates the warm mixed surface layer of the ocean from the cold deep ocean water) along the Equator. The models predict how the atmosphere-ocean system might evolve over the next one or two seasons. Once an El Niño has started, its evolution over the next six to nine months can be predicted quite accurately. Atmospheric properties elsewhere can then be inferred from these forecasts.

In Box 1.11 a summary forecast of 2002/2003 ENSO is presented, taken from the ENSO QUICK LOOK by the International Research Institute for Climate Prediction (IRI). It is based on a multiple ("ensemble") model forecast and on a probabilistic evaluation of ENSO conditions for the remainder of the year 2003. This outlook was made on January 16, 2003, and by that time, the El Niño was expected likely to continue through February 2003, followed by a weakening or even dissipation during the March to June period. Development of La Niña conditions during the second half of 2003 was expected to be slightly more likely than in an average year.

There is comparatively little accuracy in predicting the onset of an El Niño before its presence has become obvious. Nevertheless, there is considerable social benefit in predicting the evolution of an El Niño after its onset. No two El Niño (or La Niña) events are exactly the same: there are differences in their timing, duration, extent, and the location and magnitude of their impact.

1.4.2. Forecasting of weather and climate variability

The use of climate and weather forecasts represents a change from a reactive to an anticipatory stance. It requires effective monitoring and early warning systems embedded in a well-functioning response strategy. Although numerical models can predict weather for up to one or two weeks in advance, they cannot yet produce the location and magnitude of precipitation in sufficient detail for hydrological modelling, especially for the meteorological phenomena responsible for flash floods.

A seasonal climate forecast predicts how rainfall or temperature in a coming season is likely to be different from the average weather calculated over a long period of time, such as 30 years. Because the climate system is so complex, it is almost impossible to take all the factors that determine the future seasonal climate into account. So, climate forecasts are generally given in terms of the probability that rainfall or temperature will be either below normal, near normal, or above normal.

Seasonal climate forecasts can be made using three different methods: statistical, dynamical and statistical-physical.

Statistical forecasts are based on historical patterns in climate. These methods are of most value in data-rich/knowledge-poor environments. Extensive use has been made of correlation and regression methods that attempt to establish evidence of teleconnections (related climate events that are far removed in space

Box 1.10 Climate is more predictable than weather

At present, the global atmosphere is predictable only on scales of two weeks or so. An obvious question is: if the ultimate limit of detailed prediction for weather is in the order of weeks, how could we expect to predict climate on longer time scales? The answer follows directly from the definition of climate. Climate forecasts describe the predictability of weather statistics, not day-to-day variations in weather. We know that atmospheric statistics are determined by the boundary conditions of the atmosphere (i.e., sea-surface temperature (SST), land and sea ice). SST anomalies are largely responsible for predictability, and over many parts of the oceans the persistence of SSTs is in the order of months. Thus climate has more predictability than weather over seasonal time scales (NRC, 1998).

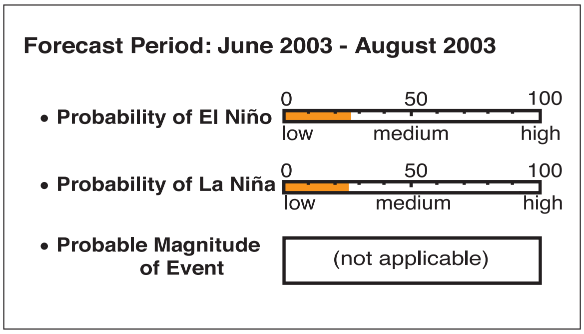
Predictability changes over a variety of time scales and with location, and climate specialists have come to realise that internal variability is an important driver in the climate system. Although there is low predictability for many regions and most seasons, there is very usable predictive skill in a few regions in certain seasons (particularly in the tropics, including Indonesia, Peru, Ecuador, southern Africa, and northeast Brazil, see Figure 1.6). The degree of climatic predictability depends on the nature of the mechanisms responsible for climate variability. Tropical SST is only one of the agents that force climate anomalies over mid-latitude continental regions, so predictability in these regions is relatively low. In a region with high predictability the experts can make good forecasts of what the climate will be like in the next season on the basis of what is happening now.

ENSO *QUICK LOOK* January 16, 2003

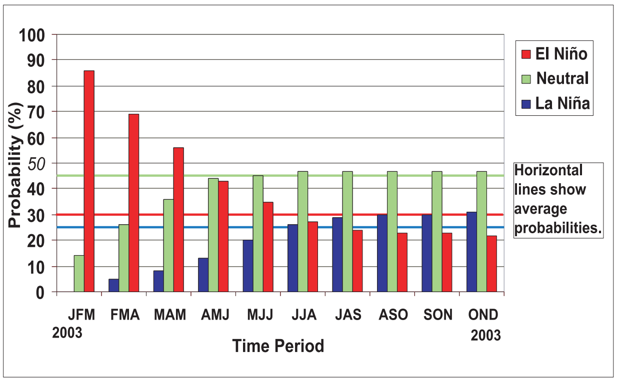
A monthly summary of the status of El Niño, La Niña and the Southern Oscillation , or "ENSO"

The current El Niño will very likely continue at least through February 2003, followed by significant weakening or dissipation during the March to June period.The outlook beyond June 2003 is more uncertain. Based on the behavior of past El Niño events and current model forecasts, it is most likely that conditions will be near-neutral during the second half of 2003, although the development of La Niña conditions is slightly more likely than in an average year. During the coming 1 to 3 months, climate effects in most regions are most likely to be weaker than those experienced during the strong 1997-98 El Niño, but could still be substantial in some regions (as some already have been). Regions commonly affected by El Niño at this time of year should remain alert to the possibility of such climate effects.

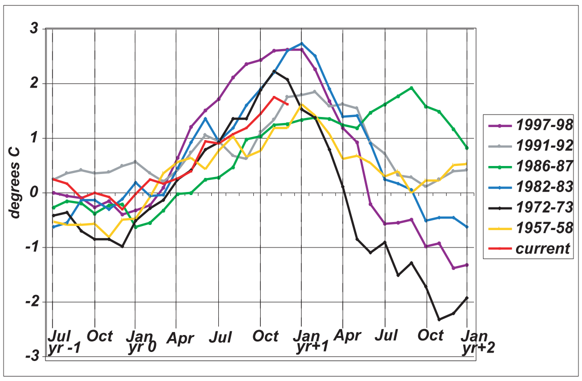
Current ENSO Forecast Summary *



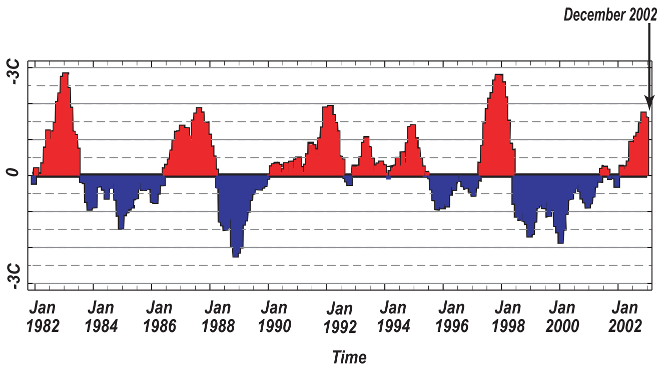
Probabilistic ENSO Forecast **



Current Conditions vs. Past El Niño**



Historical Sea Surface Temperature Index**



Historically Speaking

El Niño and La Niña events tend to develop during the period Apr-Jun and they:
- *Tend to reach their maximum strength during Dec-Feb*
- *Typically persist for 9-12 months, though occasionally persisting for up to 2 years*
- *Typically recur every 2 to 7 years*

* Probability of an El Niño refers to the likelihood of a sustained (that is, over several seasons) warming across a broad region of the eastern and central tropical Pacific, not just along coastal South America.

** Based on sea surface temperature departures from the long-term average over the "NINO 3.4" region (120-170W, 5S-5N).

(From A monthly summary of the status of El Niño, La Niña and the Southern Oscillation Reprinted by courtesy of The International Research Institute For Climate Predictions (IRI)

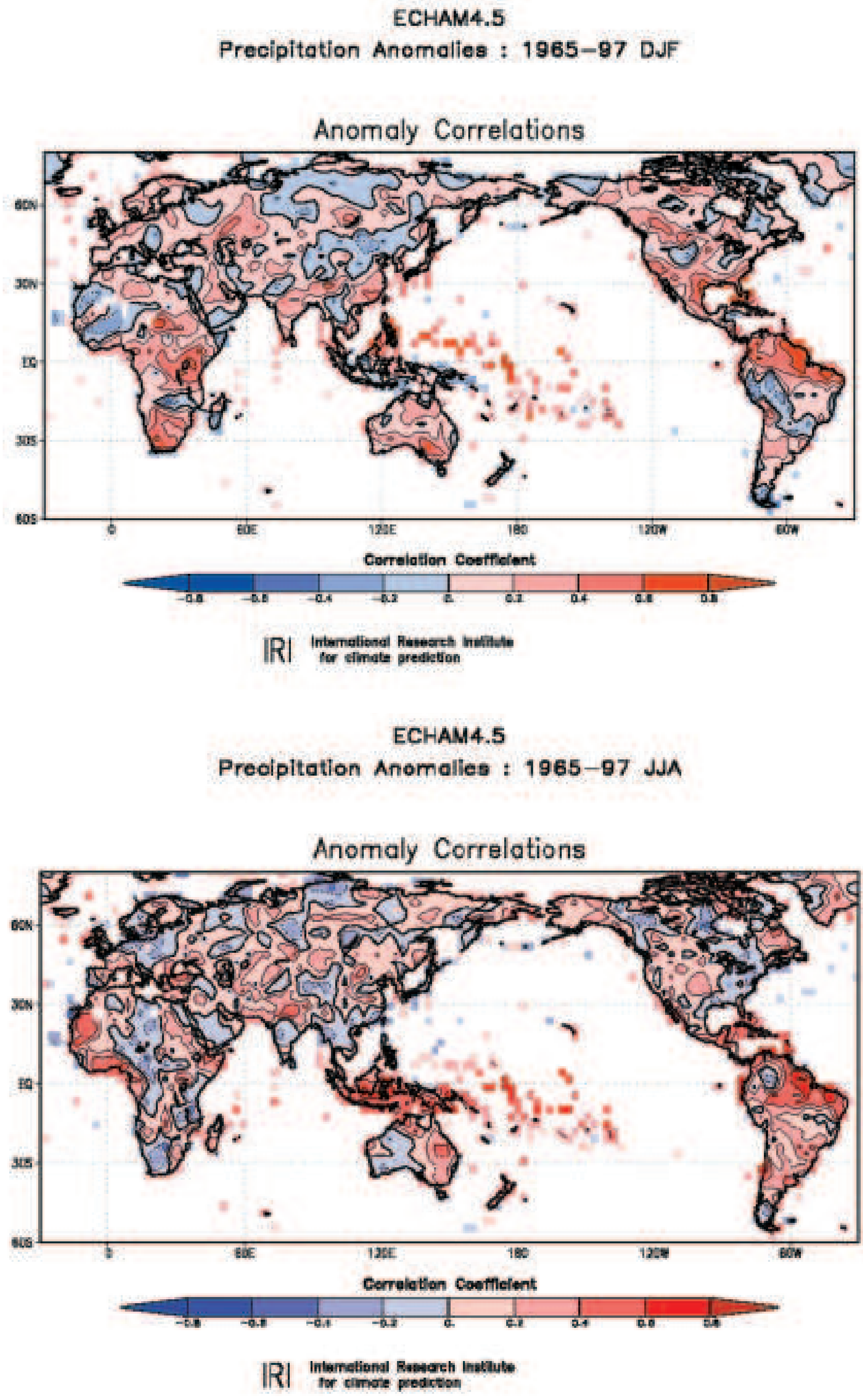


Figure 1.6 *Predictability of seasonal precipitation for the ECHAM4.5 model, 1965 to 1997. (DJF=December-January-February; JJA=June-July-August. Anomaly correlation measures the correspondence or phase difference between forecast and observations, subtracting out the climatological mean at each point. A value of 1 indicates a perfect score*

and/or time). For example, many studies have established models that link the SOI to a variety of phenomena of socioeconomic interest (e.g. inflows to water supply dams and crop yields). Most methods assume that climate processes are stationary (their generating mechanisms do not change with time or space) and linear (their relationships can be represented as straight lines between two variables, or as hyperplanes for many variables). Both assumptions are contrary to our knowledge of the climate system, but they are necessary simplifications. Recent developments in statistical science have led to the development of nonlinear forecasting methods that appear to improve prediction skill.

Dynamical forecasts are produced with a model based on the laws of physics. The model is a large collection of mathematical equations that simulate how the Earth's oceans and atmosphere work to create climate. Meteorologists tell the model what the current conditions are (e.g. SSTs, land conditions, sea ice extent), and let the equations calculate what the climate will be in the future. Typically, these models produce results on rectangular grids with spacings from 10s to 100s of kilometres apart.

Statistical-physical forecasts are produced by using statistical methods to increase the space or time resolution of dynamical forecasts. These 'downscaling' techniques provide forecast information at local scales, and are often used to connect broad climate forecasts with the information needs of mathematical models of natural or built systems and decision analysis tools.

1.4.3. Floods forecasting and early warning

Floods can be divided into three types:

(1) *river floods*, caused by rainfall and river bank overflow;

(2) *flash floods* in the hill areas due to intensive rainfall; and

(3) *tidal floods* caused by tidal and storm surges in the coastal areas during cyclones.

Forecasting and early warning systems needed for flood management can be considered in three broad categories (CARE, Bangladesh, 2000): forecasting, monitoring and base information. This section deals only with forecasting.

Flood forecasting needs to encompass all stages and aspects of floods, such as rainfall and coastal sea levels (meteorological predictions), water levels in rivers and floodplains (hydrological predictions), and predictions of, for example, the damage to agriculture and infrastructure (economic or impact predictions). In previous sections of this chapter we have focused on meteorological predictions and forecasting. Here we consider the hydrological predictions for riverine floods – a crucial part of flood forecasting.

Long term hydrological forecasts typically have a lead time of a month or more. These can only give a general indication whether there would be a risk of increased flooding, e.g. due to ENSO (see section 1.4.1), and if the coming floods are likely to be average, below or above average. These hydrological predictions depend very strongly on forecasting accuracy for weather and climate on seasonal time scales (see sections 1.4.1 and 1.4.2).

Medium term hydrological forecasts have a lead time of a few weeks, and should provide more accurate estimates of the flood conditions. These forecasts mainly depend on the quality of rainfall observation and information from the upper watersheds, additional short term climate information, and the quality of a distributed hydrological model used to calculate runoff and river flows.

Finally, *short term* hydrological forecasts, with a lead time of a few days, focus on river water levels and the extent and depth of inundation areas. This forecast is derived from a real-time observation of rainfall and river flow in the upper watershed, combined with hydrological and hydraulic models which calculate or estimate water levels in the river and water storage in the inundated areas.

As an example of an effective forecasting system in a critical flood prone area, a system developed by the Flood Forecasting and Warning Centre (FFWC) in Dhaka, Bangladesh (www.ffwc.net) is presented in Box 1.12

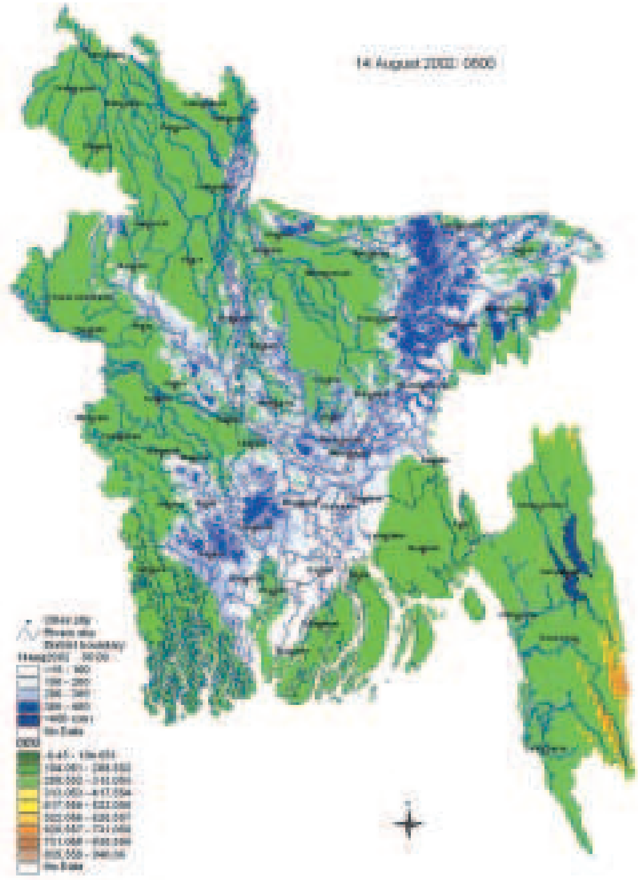


Figure 1.7 *Flood inundation map of Bangladesh for 14 August 2002. Created by combined use of a digital elevation model (DEM) and forecasted water levels by the FWWC.*

BOX 1.12. Flood Forecasting and Warning in Bangladesh

To predict water level conditions in Bangladesh, the Flood Forecasting and Warning Centre (FFWC) collects measurements of water level and rainfall, satellite pictures and simulates the water level conditions by use of a numerical model of the Bangladeshi river network. Every day during most of the monsoon season the model simulates the water level conditions during the previous 7 days (hind-cast simulations) and during the coming 3 days (forecast simulation). Results from the model simulations are used to provide flood forecasting and warning.

The outcomes of the work at FFWC are to a large extent water levels. The water levels can be divided into measured water levels and simulated water levels. The simulated water levels originate from hind-cast simulation and results from forecast simulation. Water levels can be transformed into inundation maps (see Fig 1.7). To produce the flood inundation map for Bangladesh a digital elevation map (DEM) of Bangladesh is used.

Measured, hind-casted, forecasted and transformed water levels are all determined with a given precision, but also influenced by errors originating mainly from the measurements. Water levels forecast by the system are not precise for the reasons given for hind-cast simulation and also because the model boundary conditions (water level boundaries at the Indian border and at the Bay of Bengal and rainfall over Bangladesh) needs to be extrapolated in time. The upstream water level boundaries at the Indian border in particular limits the possible forecast time. Today it is not possible to forecast the flood level in Bangladesh more than 3 days ahead. If the boundaries could be moved further upstream, i.e. inside India, it would be possible to give longer forecasts.

Source: www.ffwc.net

1.4.4 Use of forecasts by the water sector

Timely and reliable forecasts hold promise for improving economic and social well-being in both good and bad years. Nevertheless, if the consequences of accepting a given forecast are significant (e.g. water supply collapse in a major city), the forecast should be treated with caution. There is always a margin for error in any climate forecast, and users should always therefore think of adaptive and dynamic decision support systems which allow for alternative emergency pathways in case the forecast proves to be wrong.

While progress continues to be made in seasonal climate forecasting, the net benefits of using seasonal climate forecasts in water management still have to be better demonstrated. A number of factors are responsible for this situation (Bates, 2002):

- The inaccessibility of climate information and forecasts, and insufficient advocacy by climate scientists at local to international levels.
- Poor communication between water managers and climate scientists about their perceptions of research priorities and views on knowledge gaps.
- The complexity of the problems faced by water managers and the effects of political and institutional constraints on their decisions.
- Conservatism in the water sector towards funding development of new technologies and applying emerging technologies in practice, and scepticism about the accuracy and value of climate forecasts.
- Water managers have limited training in or experience with climate science.

These factors re-emphasise the need for regional water managers to share their experiences and commit to long-term dialogue with climate forecasters. Such a dialogue is necessary if climate forecasters are to build a comprehensive and accurate picture of the water managers' information needs, and for water managers to appreciate the scope and depth of recent advances in climate prediction science and the knowledge gaps that remain.

1.5 Climate change

1.5.1 Climate change and the hydrological cycle

A significant proportion of the solar energy received by the Earth is used in driving the hydrological cycle, i.e. for evaporating vast quantities of water of which 40,000 km^3 are moved and precipitated over the continents every year. Greater greenhouse gas concentrations in the atmosphere mean an increase of the available energy on the surface of the Earth and thus, according to the basics of thermodynamics, an 'intensification' of the hydrological cycle. At the global scale, all climate model simulations have verified this. (Kabat et al., 2003).

The oceans play a major role in climate, as they are able to store and release sizeable proportions of the incoming energy. Experience and the most advanced knowledge on climate processes are consistent in the prediction that the expected intensification of the hydrological cycle will not be experienced merely as a smooth linear trend, but rather in the form of oscillations of the variability of climate. The oscillations (for example ENSO) may be more frequent than in the past and the amplitude of the variability may also increase over some areas).

Most of the geochemical and biochemical substances in water are acquired during its travel from the clouds to the rivers, through the biosphere, the soils and the geological layers. Changes in the amounts and patterns of precipitation due to anthropogenic climate change alter the route and the residence time of water in the watershed and change its quality. As a result, the water might be unsuitable as a resource, not because of the quantity, but because its newly acquired quality may have render it unfit for the required use. For example, there are real risks that an increase in the concentration of dissolved salts may occur as a result of greater evaporation under higher temperatures. Increased salinity can also be associated with excesses of water. Under such conditions, water tables may rise and reach levels where the soils are salinised or contain agrochemicals or industrial wastes. Water from these shallow aquifers may eventually drain into the river network and reduce the quality of the water further downstream.

Precipitation

The IPCC Third Assessment Report (IPCC TAR) summarises projected precipitation trends as a general increase in mean annual precipitation in the Northern Hemisphere (autumn and winter) and a decrease in the tropics and sub-tropics in both hemispheres (Figure 1.11). The frequency of extreme rainfall is likely to increase with global warming, although the spatial resolution of global climate models is too coarse to provide details. Higher temperatures imply that a smaller proportion of precipitation may fall as snow.

Precipitation changes are more spatially variable than projected temperature changes. Although a general increase in precipitation is expected, some regions will see large increases, while others will see significant reductions. There is still quite a bit of uncertainty about the prediction of precipitation, for two main reasons:

- Precipitation is a secondary process in General Circulation Models (GCMs) and, as such, is poorly represented; and
- Heavy precipitation systems frequently occur on scales that are considerably smaller than the typical grid scale of GCMs, which is two to three degrees of latitude/longitude.

Evapotranspiration

Increased temperatures generally result in an increase in potential evaporation. In dry regions, potential evaporation is driven by energy and is not constrained by atmospheric moisture contents. In humid regions, however, atmospheric moisture content is a major limitation to evaporation. Studies do show increases in evaporation with increased temperatures, but models using equations that do not consider all meteorological controls may give very misleading results.

Vegetation also plays an important role in evaporation, partially by intercepting precipitation and partially by determining the rate of transpiration. Higher CO_2 concentrations may lead to increased Water Use Efficiency (WUE), i.e. water use per unit of biomass, implying a reduction in transpiration. However, higher CO_2 concentrations may also be associated with increased plant growth, compensating for increased WUE. Plants may thus acclimatise to higher CO_2 concentrations. The actual rate of evaporation is constrained by water availability.

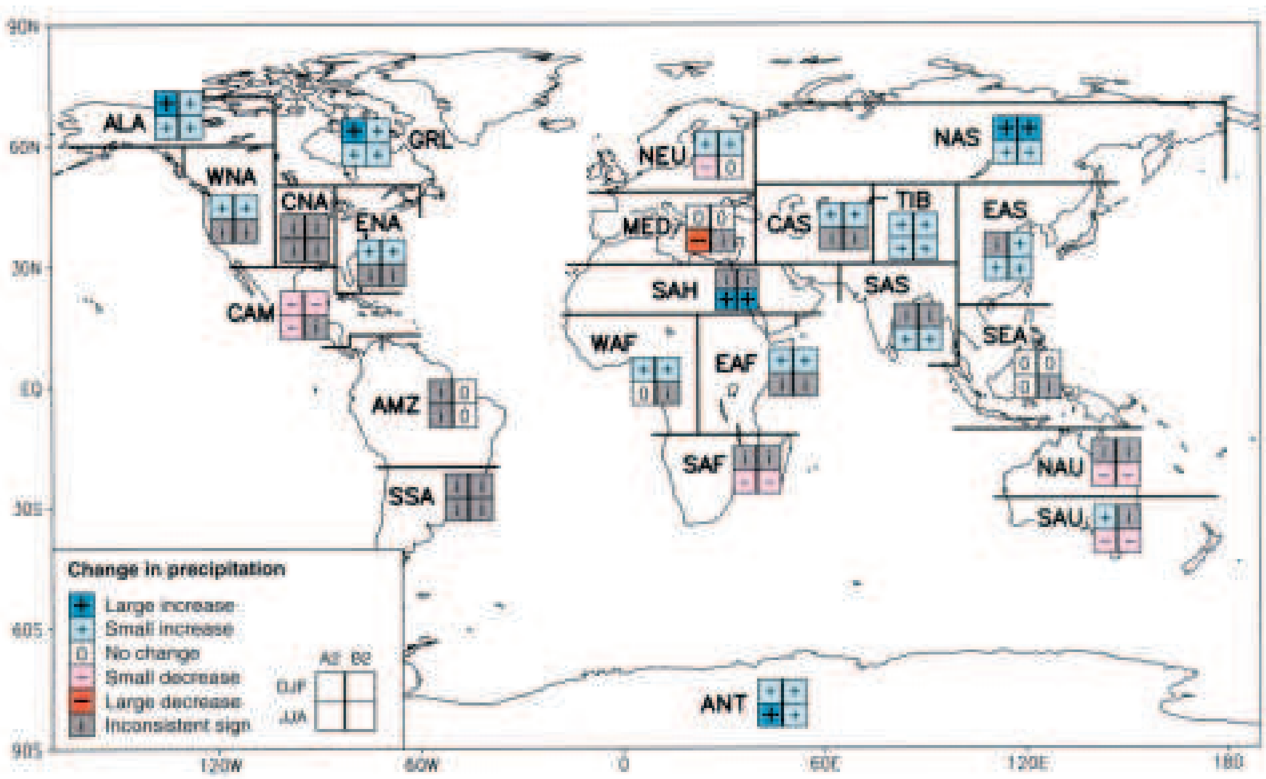


Figure 1.8 *Projected future changes in precipitation patterns, according to different models. (IPCC, 2001)*

Soil moisture

Runs with the HadCM2 GCM show that increases in greenhouse gases are associated with reduced soil moisture in the Northern Hemisphere summers. This is the result of higher winter and spring evaporation, caused by higher temperatures and reduced snow cover, and lower rainfall during the summer. The lower the water-holding capacity of the soil, the greater is the sensitivity to climate change.

Groundwater recharge

Increased winter rainfall may result in increased groundwater recharge in the Northern Hemisphere. However, increased temperatures may increase the rate of evaporation, which leads to longer periods of soil water deficits.

Shallow unconfined aquifers along floodplains in semi-arid and arid regions are recharged by seasonal streamflows and can be depleted directly by evaporation. Changes in the duration of flow in those streams may lead to reduced groundwater recharge. Sea level rise could cause saline intrusion to coastal aquifers, especially in shallow aquifers. An overlying bed that is impermeable, on the other hand, characterises a confined aquifer and local rainfall does not influence the aquifer.

River flows

Most hydrological studies on the effects of climate change have concentrated on streamflow and runoff. Streamflow is water flowing in a river channel, whereas runoff is defined as the amount of precipitation that does not evaporate. In general, changing patterns in runoff are consistent with those identified for precipitation. However, in large parts of eastern and northwestern Europe, Canada and California, a major shift in streamflow from spring to winter has been associated with a change in precipitation, but more particularly with a rise in temperature, because in winter periods precipitation has fallen as rain rather than as snow. No significant changes have been observed in colder regions.

It is not easy to pinpoint trends in hydrological data. Records are short and monitoring stations are continuing to be closed in many countries. Although there are many hydrological models which simulate river flows using climate change scenarios derived from GCMs, relatively few studies have been published for Africa, Latin America and South East Asia. Responses in different hydroclimates may be quite different. The following four examples illustrate this:

Cold and cool temperate climates: Streamflows in these areas are largely dependent on melting snow in springtime. The most important effect of climate change is the timing of streamflow. There will be more runoff during winter because less precipitation falls as snow.

Mild temperate climates: These regions are dominated by rainfall and evaporation. The magnitude of the flows is determined largely by rainfall changes. Trends show a decrease in summer runoff and an increase in winter runoff.

Semi-arid and arid regions: Here a small percentage of change in rainfall causes considerable effects in runoff.

Tropical regions: Runoff responses are largely dependent on rainfall. The number of extreme events causing flooding may increase due to increased intensity in precipitation.

Water quality

Agricultural practices may change as a result of climate change. Agricultural chemical loads in surface and groundwater may therefore change accordingly. Furthermore, higher temperatures may decrease the concentrations of oxygen and thus increase eutrophication.

Lakes

Closed (endorheic) lakes with no outflow are especially vulnerable to changes in climate conditions. These lakes are considered as good indicators of the effects of climate change. Exorheic lakes may also be sensitive to climate change. For example, levels of Lake Victoria in East Africa have increased for several years following increases in precipitation levels.

Glaciers and ice caps

On the global scale, small valley glaciers will decline as a consequence of higher temperatures. Also, some simulations show increases in mass exchange in valley glaciers through increased winter accumulation. Tropical glaciers in particular will be affected significantly by small increases in temperature

1.5.2 Sea level rise

Melting ice and thermal expansion of the oceans are the two primary drivers of sea level rise. As the sea rises, there are four main impacts that are of concern:

- Increased coastal erosion: Sea level rise, more extreme weather, and a loss of sea ice will contribute to more erosion and flooding along vulnerable Arctic shorelines. Higher sea levels with less ice cover will expose more of the coast to both normal waves and more powerful storm waves.
- Flooding, inundation and displacement of wetlands and lowlands: Land presently at the margins of tide and wave action may be inundated and accelerated erosion of dunes may occur in response to higher wave action associated with raised water levels.
- Impairment of water quality in freshwater aquifers and estuaries: Due to low elevation and small hydraulic gradient, coastal plain groundwater resources of the southeastern United States are potentially vulnerable to salinisation from sea level increase. Saline intrusion in the lower reaches of the deltas would be aggravated by the predicted sea level rise and may warrant revised management of flow control

- Reduced protection from extreme storm and flood events: Higher sea levels provide a higher base for storm surges to build on, making severe floods more likely.

1.5.3 Climate change scenarios for water resources management

The impacts of climate change on hydrology and water resources are usually assessed by defining scenarios for changes in climatic inputs to a hydrological model. These scenarios are derived from the output of General Circulation Models (GCMs), which use scenarios of the future emissions of greenhouse gases as an input for their calculations. Emission scenarios are developed based on socio-economic projections for the world. Problems arise, however, when downscaling GCM results to the scale of inputs used by basin-scale hydrological and water management models. In effect, the greatest uncertainties in the results from these models relate to using climate change scenarios where the precipitation patterns from the coarse gridded GCMs are uncertain.

Emission Scenarios

For its Third Assessment Report (TAR), the IPCC prepared a total of 40 emission scenarios (IPCC Special Report on Emission Scenarios – SRES). The scenarios were based on the emission driving forces of demographic, economic and technological evolution that produce greenhouse gas (mainly carbon dioxide) and sulphur emissions. None of the scenarios assumes explicitly the implementation of the United Nations Framework Convention on Climate Change (UNFCCC) or the Kyoto Protocol targets.

Four scenario 'storylines' were developed (the list below has been adapted from IPCC TAR, 2001, Working Group I Box 9.1, p. 532):

- *Storyline A1*: This scenario describes a future world of very rapid economic growth, global population that peaks in the mid 21st century and declines thereafter, and the rapid introduction of new and more efficient technologies. Major underlying themes are convergence among regions, capacity building and increased cultural and social interactions, with a substantial reduction in regional differences in per capita income. This family is divided into three groups that are distinguished by their technological emphasis: fossil intensive (A1FI), resulting in atmospheric CO_2 concentration increasing from present 370 ppm to almost 1000 ppm by the year 2100; non-fossil sources (A1T), atmospheric CO_2 550 ppm in 2100; and balance (A1B), atmospheric CO_2 700 ppm in 2100.

- *Storyline A2*: The A2 scenario describes a very heterogeneous world. The underlying theme is self-reliance and preservation of local identities. Fertility patterns across regions converge very slowly, which results in continuously increasing population. Economic development is primarily regionally oriented and per capita economic growth and technological changes are more fragmented than in other storylines.

- *Storyline B1*: The B1 scenario describes a convergent world with the same global population as the A1 scenario (population that peaks in mid-century and declines thereafter), but with rapid change in economic structures towards a service and information oriented economy, with reductions in material intensity and the introduction of clean and resource-efficient technologies. The emphasis is on global solutions to economic, social and environmental sustainability, including improved equity, but without additional climate initiatives.

- *Storyline B2*: The B2 scenario describes a world in which the emphasis is on local solutions to economic, social and environmental sustainability. It is a world with a continuously increasing global population, at a rate lower than that in the A2 scenario, with intermediate levels of economic development, and less rapid and more diverse technological change than in the B1 and A1 storylines. While the B2 scenario is also oriented towards environmental protection and social equity, it focuses on local and regional levels.

The computed resulting emissions of CO_2 according to these scenarios are shown in Figure 1.9.

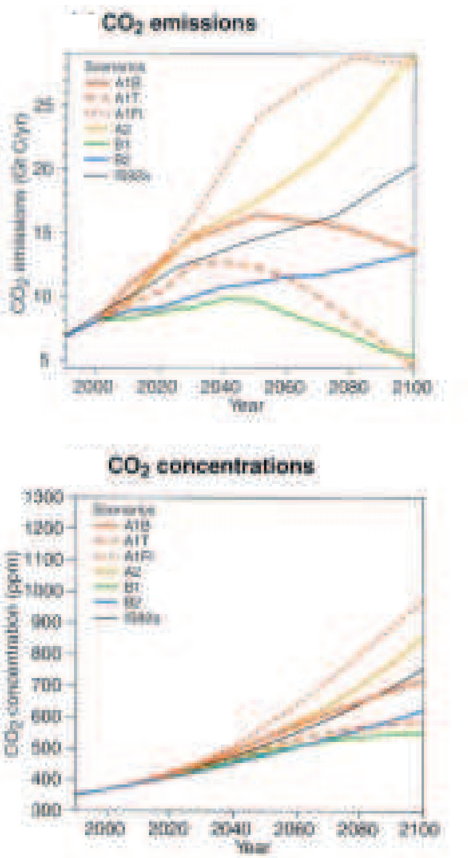


Figure 1.9. *Greenhouse gas emissions according to different scenarios (IPCC Third Assessment Report-TAR, 2001). For the fossil fuel intensive scenario (A1FI), the atmospheric CO_2 concentration is projected to increase from present 370 ppm to almost 1000 ppm by the year 2100, for non-fossil sources based economy (A1T) atmospheric CO_2 will rise to 550 ppm in 2100, and for a "balanced" scenario (A1B), it is projected to be 700 ppm in 2100. IS92a series refer to the emission scenarios developed for the IPCC Second Assessment Report.*

Climate Change Scenarios

Based on the emission scenarios, IPCC TAR modelled possible future pathways of temperature, precipitation and sea level using coupled Atmosphere Ocean General Circulation Models (AOGCMs). Because of computing limitations, only the so-called 'draft marker scenarios' A2 and B2 were used for AOGCM model runs. The results from the simple climate models for all 'marker' scenarios (which are considered the most illustrative) are shown below in Figures 1.10 and 1.11. From 1990 to 2100, the globally averaged surface temperature is projected to increase by between 1.4 and 5.8 °C and global mean sea level is projected to rise between 0.09 and 0.88m, depending on the emission scenario.

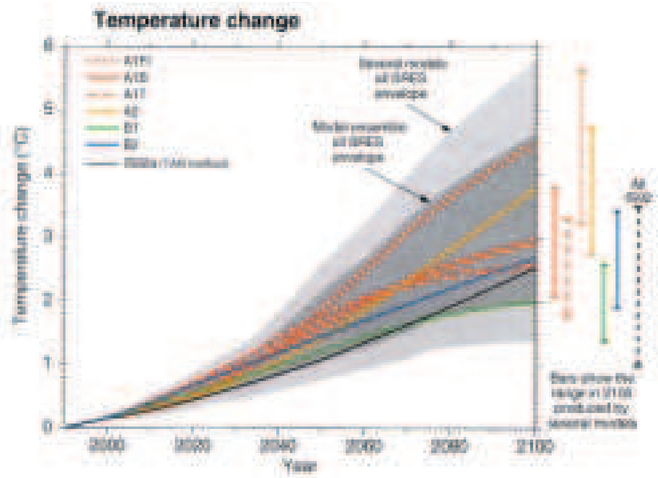


Figure 1.10. *Global temperature projections, according to different scenarios (IPCC, 2001)*

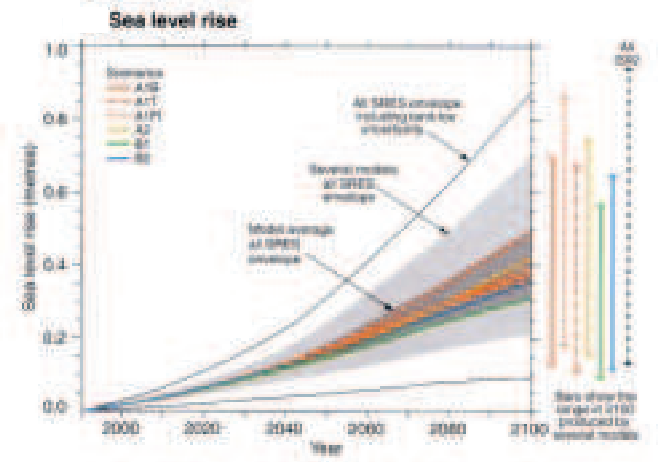


Figure 1.11. *Global sea level rise projections according to different scenarios (IPCC, 2001)*

Figures 1.10 and 1.11 show projected temperature increases and sea-level rises for the period 1990 to 2100 each for six marker scenarios. The bars at the right of the figures indicate ranges.

Climate change scenarios for hydrological and water resources applications

Climate change scenarios produced by the General Circulation Models are global, which means they have limited spatial resolution, typically in the order of hundreds of kilometres. While these scenarios can be used for studies on the impact of climate change on water resources at global scale, they are not directly suitable as climate drivers for regional and catchment-scale studies. There is a basic problem of availability of climate change projections on a regional scale, which is often seen by water managers as a major source of uncertainty, hindering the planning and decision making process.

In order to obtain information at spatial scales smaller than a grid-box in a GCM, it is necessary to 'downscale'. There are two broad approaches to downscaling, neither of which is inherently superior to the other, and either of which may be appropriate in a given situation. These approaches are:

- Statistical downscaling, where an equation is obtained empirically to capture the relationship between small-scale phenomena and the large-scale behaviour of the model. By far the majority of the studies into the effects of climate change on river flows at regional and catchment scales have used this technique, by applying large scale changes in climate to observed climate projected by GCMs input data to create perturbated climate series.
- Dynamical downscaling, where a high-resolution regional climate model (RCM) is embedded within a GCM. This technique is relatively recent and still subject to improvements. Major problems concern direct error propagation from the global GCM to the regional model. Resulting regional scenarios will have a higher spatial resolution, but still carry the same or even larger uncertainties as the global scenarios. Also excessive computing power is needed to generate longer data series
- Combination techniques, using regional models, statistical downscaling and observed regional climate data in so-called "data assimilation" modelling. This highly specialised technique is currently under development and requires further research into its wider applicability .

1.5.4 Impacts of climate change on water resources availability

The impacts of climate change on hydrology and water resources are usually assessed by defining scenarios for changes in climatic inputs to a hydrological model. These scenarios are derived from the output of GCMs. Problems arise, however, when downscaling GCM results to the scale of inputs used by basin-scale models. In effect, the greatest uncertainties in streamflow predictions from hydrological models using climate change scenarios are caused by the fact that the precipitation patterns from the coarse-gridded GCMs are uncertain.

River catchment scale

There are many modelling studies addressing changes in hydrological regimes and in water resources availability under different climate change scenarios. IPCC TAR

Box 1.13 Climate change impacts on water resources

Climate change will lead to an intensification of the global hydrological cycle and can have major impacts on regional water resources, affecting both ground and surface water supply for domestic and industrial uses, irrigation, hydropower generation, navigation, in-stream ecosystems and water-based recreation. Changes in the total amount of precipitation and in its frequency and intensity directly affect the magnitude and timing of runoff and the intensity of floods and droughts; however, at present, specific regional effects are uncertain.

The impacts of climate change will depend on the baseline condition of the water supply system and the ability of water resource managers to respond not only to climate change but also to population growth and changes in demands, technology, and economic, social and legislative conditions. In some cases - particularly in wealthier countries with integrated water-management systems - improved management may protect water users from climate change at minimal cost; in many others, however, there could be substantial economic, social and environmental costs, particularly in regions that already are water-limited and where there is considerable competition among users. (IPCC TAR, 2001)

summarises dozens of catchment-scale studies published in the literature (IPCC TAR 2001: Impacts, Adaptation and Vulnerability, page 202). A general conclusion across many of these studies is that the effects of a given climate change scenario vary with the catchment's physical and land use characteristics, and that small headwater streams may be particularly sensitive to a change. It needs to be noted that, although many of these studies provide valuable insight into sensitivity of hydrological systems to changes in climate, very few of them are actually assessing the potential effects of future global warming. There is plenty of information in Europe and USA, but relatively few studies has been published about Africa, Latin America and SE Asia.

Global Scale

Modelling studies at global scale often combine impacts of climate change with other key pressures on the world's water resources, such as population and economical growth.

Vorosmarty et al. (2000) investigated global distribution of water resources in 2025 compared with present-day demand for three scenarios: climate change only, population growth only, and the combination of both. The results show changes in total water withdrawal over available water supply for the three scenarios, relative to contemporary (base) conditions. Although the study attributes most water scarcity in 2025 to direct impacts of population growth, and not to climate change, the complex interplay between growing water demands and climate change really requires a high resolution, regional perspective.

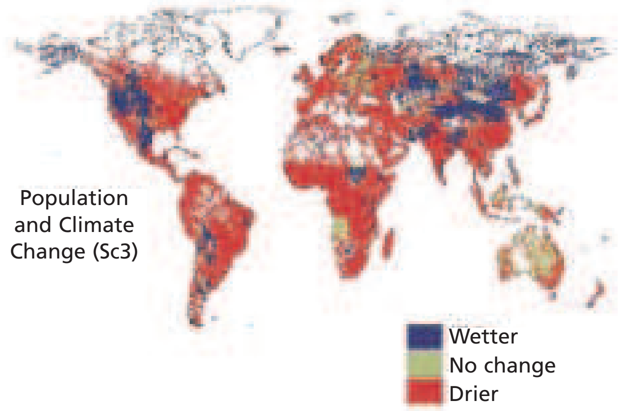


Figure 1.12. *Water Resources Situation in 2025 as a result of a combined scenario (Sc3) of climate change and population growth. After Vorosmarty et al, 2000.*

As a contribution to the Dialogue on Water and Climate, Alcamo et al (2002) modelled future climate impacts on water resources. First, changes in global precipitation by 2020 and 2070 have been illustrated for the A2 and B2 SRES global emissions scenarios, and based on two different climate models (Hadley Centre climate model- "HadCM3", and the model from the Max Planck Institute - "ECHAM4"). Under the typical emission scenario, climate models tend to estimate that the world as a whole becomes more moist (largely because of increased evaporation of the oceans) and hence precipitation increases over most of the land area (see, e.g Fig 1.13a). Nevertheless, and of great importance, some large areas experience a decrease in precipitation. The changes in precipitation, either upwards or downwards, are already significant in many regions in the 2020s and become more intense by the 2070s (Figure 1.13b).

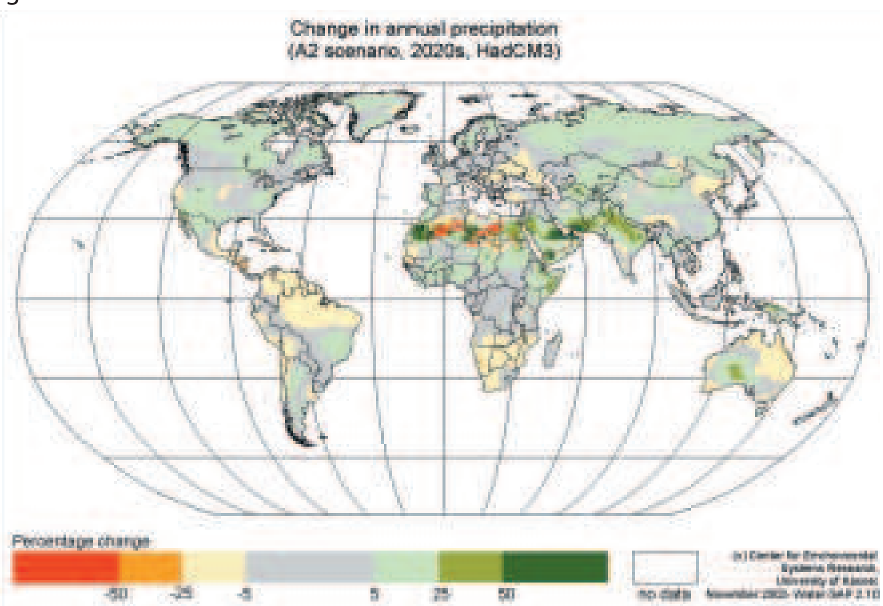


Figure 1.13a.

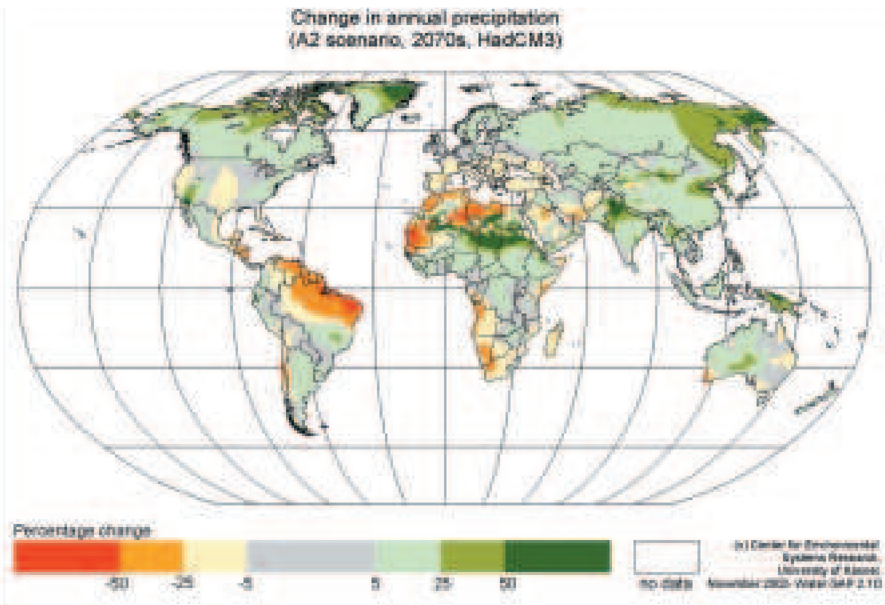


Figure 1.13b.

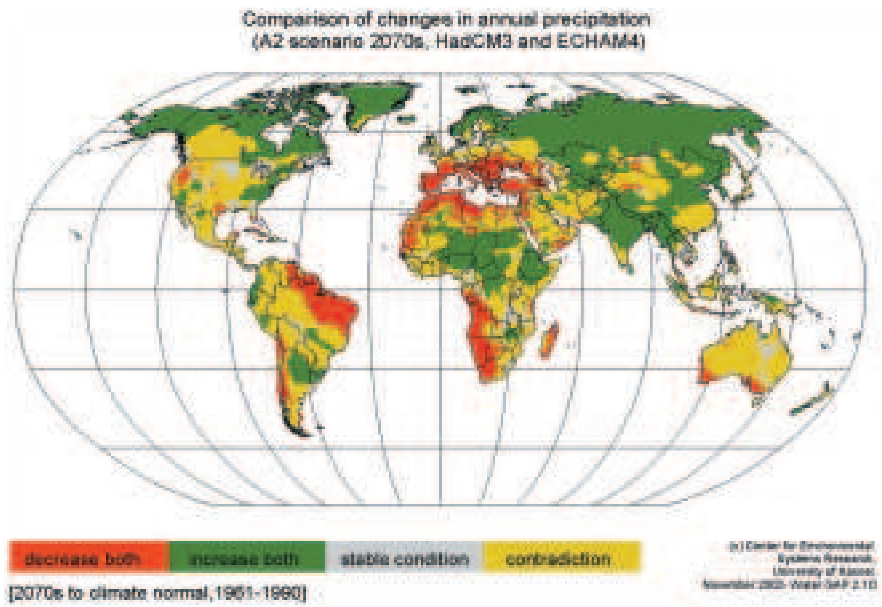


Figure 1.13c.

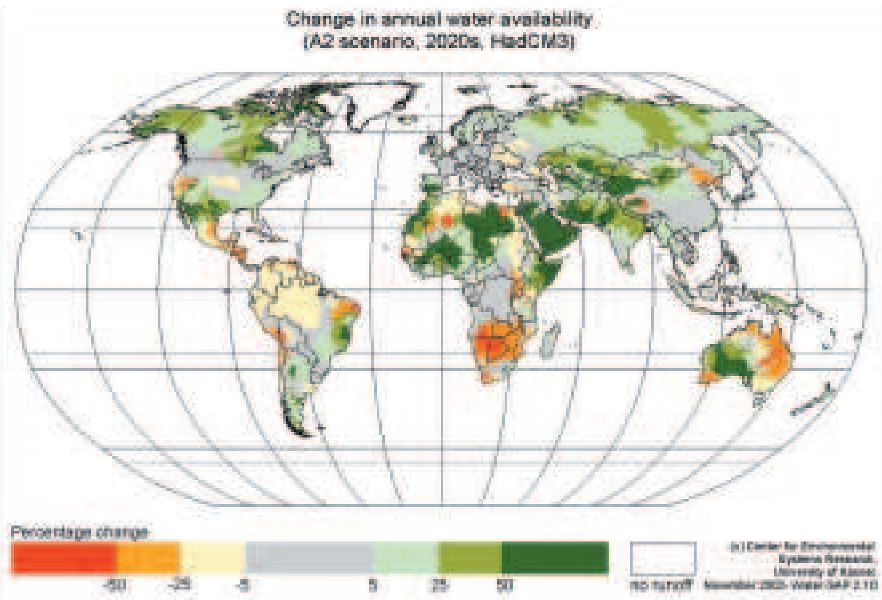


Figure 1.13d.

Figure 1.13c illustrates the range of uncertainty in climate model predictions. For some regions of the world, Hadley Centre climate model ("HadCM3") and the model from the Max Planck Institute ("ECHAM4") give different directions for precipitation change. Nevertheless, in many regions the differences are small, and for many important regions, the precipitation estimates are consistent in both models. For example, both models predict less precipitation in the arid regions of Southern Europe, the Middle East and Northeast Brazil.

Changes in average water availability calculated for 2020 and 2070 HadCM3 – A2 scenarios are shown in Figures 1.13.d and 1.13.e. An increase or decrease in precipitation will proportionally raise or lower the volume of river runoff. Meanwhile the expected increase in air temperature will tend to increase evapotranspiration everywhere, and hence decrease runoff. These two effects interact at different locations to give a net increase or decrease in runoff. Under both the A2 and B2 scenarios much of the world will experience an increase in annual water availability (figures 1.13d and 1.13e show the results only for A2), but some large regions will have decreasing runoff. This includes regions already experiencing water scarcity such as the Middle East, Northeast Brazil, and Southern Africa. These regions will probably become more and more critical in terms of average water availability for livelihoods. In Chapter 3 additional discussion is presented about how seasonal climate variability, such as ENSO, superimposed on climate change scenarios, may exacerbate the level of criticality in water availability in these and other regions.

1.5.5. What may happen to climatic extremes under climate change?

Since climate extremes which result in floods and droughts are of particular importance for water-related issues, and since these extremes may increase with global warming, it is imperative that water resources managers be aware of current forecasts of climate change, of their likelihood of

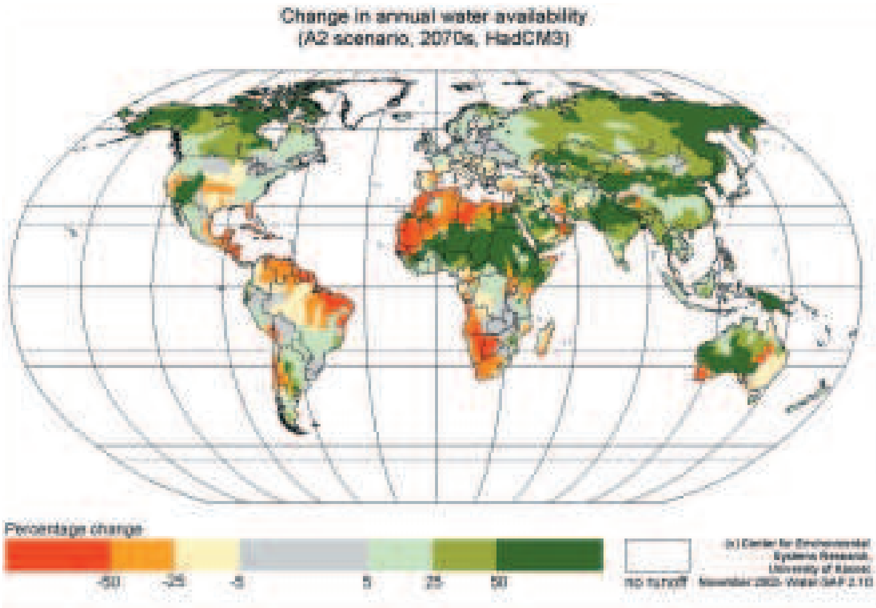


Figure 1.13e.

occurrence and their likely effects on water resources. The confidence that may be attached to our understanding of changes in climatic extremes in the past and in the future is summarised in Table 1.3 (2001), which was drawn from the most recently published IPCC assessment.

Climate change projection	Climatic change already observed?	To occur in the 21st century?	Effects on water resources
Higher maximum temperatures and more hot days over nearly all land areas	Likely	Very likely	Water resources reduced
Higher minimum temperatures, fewer cold days and frost days, over near all land areas	Very likely	Very likely	Water resources reduced
Diurnal temperature ranges reduced over most land areas	Very likely	Very likely	
Increases of heat index over land areas	Likely over many areas	Very likely over most areas	Water resources reduced
More intensive precipitation events	Likely over many northern hemisphere mid-to-high latitude areas	Very likely over many areas	More frequent and more severe floods
Increased summer continental drying and associated risk of drought	Likely in a few areas	Likely over most mid -latitude continental interiors	More frequent and more severe droughts
Increases in tropical cyclone peak wind intensities	Not observed in the few analyses available	Likely over some areas	More frequent and more severe storm-surge floods
Increases in mean and peak precipitation intensities in tropical cyclone	Insufficient data	Likely over some areas	More frequent and more severe floods

***Table 1.3** Summary of already observed changes, prospects for the future and likely impacts on water resources (Source: IPCC, 2001)*

Will the behaviour of ENSO change?

Adverse effects have already been observed in water-related extremes linked to climatic variability. As the warm phase of ENSO has become more frequent, persistent and intense since the mid-1970s (see Section 2.2.2), extreme weather-related events occur more frequently - intensive precipitation and floods in some locations and precipitation deficits and droughts in other regions.

Any changes in ENSO due to climate change will impact the incidence and tracks of tropical cyclones (including hurricanes and typhoons). During El Niño, the incidence of hurricanes typically decreases in the Atlantic and far western Pacific and Australian regions, but increases in the central and eastern Pacific. The question of whether a warmer atmosphere is likely to produce stronger and more frequent El Niños has yet to be resolved. Current models of the global climate system cannot yet simulate El Niño, tropical storms and greenhouse-gas warming together.

Flood Frequency

Flood magnitude and frequency are likely to be increased by climate change in most regions of the world (IPCC, 2001). The general direction of change in extreme flows and flow variability is broadly consistent among IPCC climate scenarios, though confidence in the likely magnitude of change in any particular catchment is low. There are a number of possible reasons why, in a warmer future climate, the frequency of floods may increase in any particular region:

- more frequent wet spells in middle and high latitude winters;
- more intense mid-latitude storms;
- a more El Niño-like mean state for the ENSO cycle;
- an increased frequency of extreme precipitation events;
- increased magnitudes of precipitation events of high intensity; and
- land use change and surface degradation (e.g. deforestation, urbanisation).

Relatively few studies have assessed climate change effects on flooding frequencies. Reasons for this are that until recently GCMs produced relatively coarse scenarios, given as monthly averages with wide spatial and temporal resolution. Short-duration rainfall studies cannot be made from these projections. One example of a flood frequency study was that conducted by Mirza (1997) for South Asia. According to four GCM scenarios, the flood discharges in the Ganges-Brahmaputra-Meghna (GBM) basin were estimated to increase by 6-19%.

Milly et al. (2002) hypothesised that climate change might be associated with the apparent increase in the incidence of great floods in the 29 basins they considered. They used a 300-yr 'idealised CO_2 quadrupling' experiment, with a 1%-per-year growth (for 140 yr) of atmospheric CO_2 concentration from the control level to a stable, quadrupled level (which was then steady for 160 yr). Using climate sequences obtained from a numerical climate model, they found that in all but one of the basins the 100-yr flood for present day conditions was exceeded more frequently as a result of the CO_2 quadrupling scenario. In half of the river basins, the return period of the present-day 100-yr flood peak decreased to less than 12.5 years (Table 1.4). The observed increase in the incidence of great floods was found to be consistent with results obtained from the climate model, and the model results suggest that the trend will continue.

Palmer and Räisänen (2002) analysed the output of 19 climate models and estimated that, over the next century, very wet winters will be up to five times more likely than today for much of central and northern Europe. They also predict that the probability of very wet summers in the Asian monsoon region will rise by a similar magnitude, increasing the risk of flooding. By applying a simple 'cost-loss' analysis to a hypothetical investment decision, they show that for extreme events it is better to consider the changing frequency in a set of different climate-change projections (the 'probabilistic' approach), than to rely on a single model projection (e.g., Milly et al, 2002) or on the averaged projection from several climate models (the 'consensus' approach used regularly by the IPCC).

River	Station	Projected return period of current 100-year flood peak under quadrupled atmospheric CO_2 concentration (years)
Yukon	Eagle, USA	9
Nelson	Bladder Rapids, Canada	11,5
Fraser	Hope, Canada	4
St Lawrence	Cornwall, Canada	8
Mississippi	Keokuk, USA	111
Ohio	Metropolis, USA	43
Danube	Orsova, Romania	22
Neva	Novosaratkova, Russia	3,5
Ob	Salekhard, Russia	13
Yenisei	Igarka, Russia	17
Lena	Kusur, Russia	10
Amur	Khabarovsk, Russia	42

Table 1.4 *Projected changes in the frequency of large floods (Milly et al., 2002*

The findings of Milly et al. (2002) and Palmer and Räisänen (2002) are cause for concern. However, they are of limited value for water and flood management planning in most river basins. Schnur (2002) correctly points out that current climate models are not good at predicting extreme climate events in local areas because they are limited in their resolution to a coarse grid size of about 200 kilometres.

For typical river basins, climate-change simulations would need a much higher spatial resolution (in order of tens of kilometres or less). Until computational power increases significantly, climate and hydrology science will have to "patch" models together, taking the results of ensemble climate projections on coarse grids, for example, and inserting their output into statistical 'downscaling' techniques or high-resolution hydro-meteorological models for a specific river catchment.

Drought frequency

Droughts are more difficult to define in quantitative terms than floods, as they can imply rainfall deficits, soil moisture deficits or lack of flow in the river. Not only climatic and hydrological inputs, but also changes in water resources management, may affect drought. There are a number of possible reasons for an increase in the frequency and severity of droughts in any particular region (IPCC, 2001):

- There is a growing risk of summer droughts in most mid-latitude continental interiors during the 21st century. Less precipitation and higher temperature may occur simultaneously, reducing available water resources while at the same time increasing evaporative demand.
- As temperatures increase and evaporative demands from crops and natural vegetation increase, these demands can be met only up to a point, as the consequent loss of water in the soil may not be compensated for by increases in precipitation.
- It is possible that in many different regions there will be an increased risk of droughts arising from more frequent and/or more intense El Niño events.
- In many regions changes in the seasonal distribution of precipitation may have even more marked impact upon water resources than changes in total annual precipitation.

The effects of any decrease in precipitation may be amplified through the hydrological system. Runoff in semi-arid and arid regions in particular will decrease at a much higher rate than underlying decreases in precipitation. Groundwater recharge and hence groundwater resources may decrease even more than the change in runoff. On a regional basis, the expected impacts of climate change on droughts need to be evaluated in connection with other related adverse effects, such as land degradation and desertification. For the West African Sahel, and northern and southern Africa, projected future changes in rainfall together with more intensive land use would exacerbate the desertification processes. In arid and semi-arid Asia, the runoff and water-availability may decrease, and the reduced soil moisture in summer would exacerbate already severe land degradation and desertification. Enhanced land degradation and desertification due to climate change is also expected in some areas of Australia and Latin America.

Some modelling studies have linked higher ocean temperatures to global warming. Hoerling (Science, January 2003) found that the warm oceans, coupled with

Box 1.15 Assessment of drought risk

It would be imprudent to assess drought risk by examining only the potential effects of climate change. Major droughts have occurred in the past as part of natural climate variability. For example, around 1550 AD a mega-drought occurred in Mexico, possibly resulting in the death of over 80% of the Indian population. Therefore, it is important to understand, by a combination of retrospective data analysis and modelling, the role of natural climate variability in triggering major droughts and any potential amplification by climate change.

the effects of La Niña, worked together to trigger the droughts in Afghanistan and Southern Europe, as well as the United States. This study provides substantiating evidence for our expectation that climate change effects (in this case warmer ocean) could "superimpose" on the impacts of the current natural climatic variability (ENSO), and make the overall problem (in this case droughts) more severe and persistent.

Hunt and Elliot (2002) have investigated the genesis and assessed the properties of major droughts in the Mexican region. Their analysis was based on a 10,000-year numerical climate model run for present day conditions. They found one mega-drought and 12 other droughts lasting a decade or longer within the 10,000-year climate sequence, with an average reduction in annual mean rainfall of 20-40 % per annum averaged over the drought episodes. This suggests that large droughts in the Mexican region have a return period of less than 800 years under natural climate variability, which is not a trivial problem for this region.

1.5.6 Implications for water resources engineering

Water managers' routine activities include water allocation among multiple and often competing uses, minimisation of risk, and adaptation to changing circumstances such as variability in water storage levels and water demand due to seasonal effects and/or population growth. A wide range of adaptation techniques has been applied over many decades: capacity expansion (e.g., building new reservoirs), changing operating rules for existing water supply systems, managing water demand, and changing institutional practices. Within this context, historical climate and hydrological records provide the basis for the determination of reliable water yields from water resources and assessment of flood and drought risk (Figure 1.14). Underpinning these investigations is the assumption that the statistical properties (e.g. averages and standard deviation) of the climatic and hydrological variables remain constant over time.

The prospect of climate change means that the key climate and hydrological variables will change, as will water demand (Figure 1.15). Climate-induced effects may be nonlinear, and carry the potential for surprises beyond those already incorporated in water supply system designs and existing water management strategies. The consequences of such surprises will depend on factors as diverse as: (1) the speed and cumulative extent of the change in climate; (2) the condition of existing infrastructure; (3) the number and nature of the options available for adaptation; (4) the wealth of the nation concerned (i.e. availability of human and financial captial, state of the environment, etc); (5) the degree of technological sophistication among water managers, users and stakeholders; (6) the effectiveness of local water governance under current and projected future conditions; and (7) the ability of the local population to change residential and work locations.

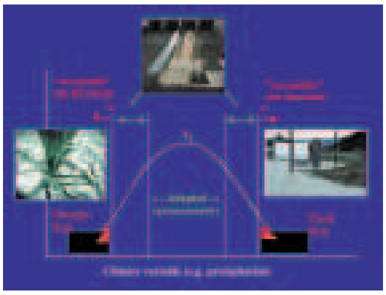


Figure 1.14. *Adaptation and risk in the context of present-day climate (after Warrick, 2002)*

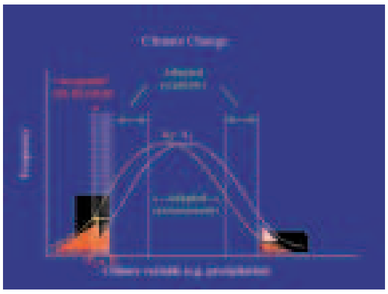


Figure 1.15. *Adaptation and risk under climate change*

In the remainder of this report, we look in more detail at the implications of these factors for water managers seeking to cope with the present impacts of climate variability and the long-term effects of climate change.

Identifying the practical implications of climate change for water engineering remains an elusive task. It will remain for some time an attempt to materialise in very concrete terms what are, at this stage, rather uncertain set of hypotheses, predictions and scenarios, with consequences decades away (Loaiciga et al, 1996.

A focus on increasing climate variability, however, is far less remote. Water resources engineers routinely deal with issues concerning structural safety, quality of services, planning and impacts of water projects, all of which are affected by hydrological uncertainties. Their decisions are based on historical data or projected trends from observations. "Future" climatic events have so far been incorporated in most water engineering decision making by assuming that the future would be a statistical replica of the hydrological regime observed in the past. More complete, longer and better consolidated data series on day-to-day variation of climate and hydrological parameters need now to be analysed, in order to be able to apply more sophisticated time-series and stochastic hydrological analysis and projections to reflect evident increasing climate variability.

Chapter 2: Impacts

The scientific analyses in Chapter 1 show conclusively that climate variability and climate change need to be mainstreamed into water resource planning and management. We saw there how present and predicted future climate patterns force water managers to re-evaluate the availability and reliability of future water supplies. What does that mean for the "clients": the men, women and children who depend on a safe supply of water for drinking, cooking, hygiene and basic sanitation; the farmers whose crops need timely and plentiful watering in the growing season; the industrialists whose machinery must be cooled and lubricated on a continuous basis; the power utilities whose hydroelectric turbines perform best with full reservoirs and whose thermal stations demand copious cooling water? And what of nature itself? How can the minimum river flows and seasonal volumes needed to sustain valuable aquatic ecosystems be guaranteed in this climate of uncertainty?

Population growth is a primary driver in virtually all development sectors. The availability of sustainable water supplies is also a crucial factor in most of them. Together, they condition the progress that any country can achieve towards the targets of poverty alleviation, sustainable development and good governance. It is an unfortunate fact that the nations that contribute most to the greenhouse gas concentrations driving climate change are not the ones that will suffer most from its consequences. Vulnerability is a function of location and capacity to cope. On both counts, it is the poor in the developing world who are hardest hit by storms flood and droughts, and by the longer term impacts of global warming and sea level rise. In this chapter, we look at what the climate predictions of Chapter 1 imply for the livelihoods of future populations and for the ecosystems on which so many people depend.

Not all the prognoses are doom-laden. For example, climate change will affect the number of people at risk of hunger. Crops grow faster in a warmer climate, but they also need water at crucial times. According to a study by Fischer et al. (2002), the combined impact of climate change will be of global significance only if super-imposed in a situation with an already high level of under-nourishment (see section 2.3.4). In all other cases, with stabilising population levels and rapid economic growth, poverty, and with it hunger – though negatively affected by climate change – would become less prevalent than it is today.

It was in recognition of the immense challenges that humanity faces in creating a more equitable world, that the Millennium Development Goals were established to help promote sustainable development in developing countries throughout the world. The additional stress that will occur on society and nature due to climate variability and change will increase the challenge of achieving these goals.

A high priority goal, reinforced by world leaders at the World Summit on Sustainable development in Johannesburg in 2002, is ensuring that people have enough water for basic needs: water supply, sanitation, and food production. The challenge is enormous: over one billion people still lack access to safe water, and more than two billion lack safe sanitation. Slow progress is not acceptable, as more than three million people still die every year from avoidable water-related disease. Meeting this challenge will be made more difficult not only by socio-economic factors such as increases in population, but also by the upward trend in extreme weather and climatic events. Yearly economic losses from large events have increased ten-fold between the 1950s and 1990s.

Figure 2.1 shows that although water-related climate extremes strike developed and less developed countries alike, their consequences are very different. In developed countries, the material flood losses continue to grow, while the number of fatalities decreases. For catastrophic floods in developing countries, particularly in Asia, the number of fatalities is still very high relative to the developed countries.

While there may be uncertainty over the scale of climate variability and change by 2015 (the first time horizon set for achieving Millennium Goals), there is no dispute about the increase in both precipitation variability and global temperature rise over the past years and this trend is very likely to continue (see Chapter 1). Evidence suggests that even small changes in the magnitude of extreme climate events have an exponential effect on losses, and so the increasing trend in the frequency and magnitude of these events could derail progress towards many of the Millennium targets.

Although figures show that at the global level the increase of water demands and uses is the determinant driver in what can be considered as a looming crisis, it must be pointed out that the relationship of humans with water is largely defined at the local level, with water being considered either as a resource or as an ecosystem. Global and even national indicators hide the obvious fact that for all beings, scarce water means survival and no water at all means death within a few days. In many stressed environments, the resource component in the demand/supply balance may, indeed, become the key issue if the resource is modified in total amount or in its temporal or spatial distribution by, for example, changes to mean climates and climatic variability.

Before looking at how water availability and reliability may affect the different water users, it is helpful to see how much water there is going to be.

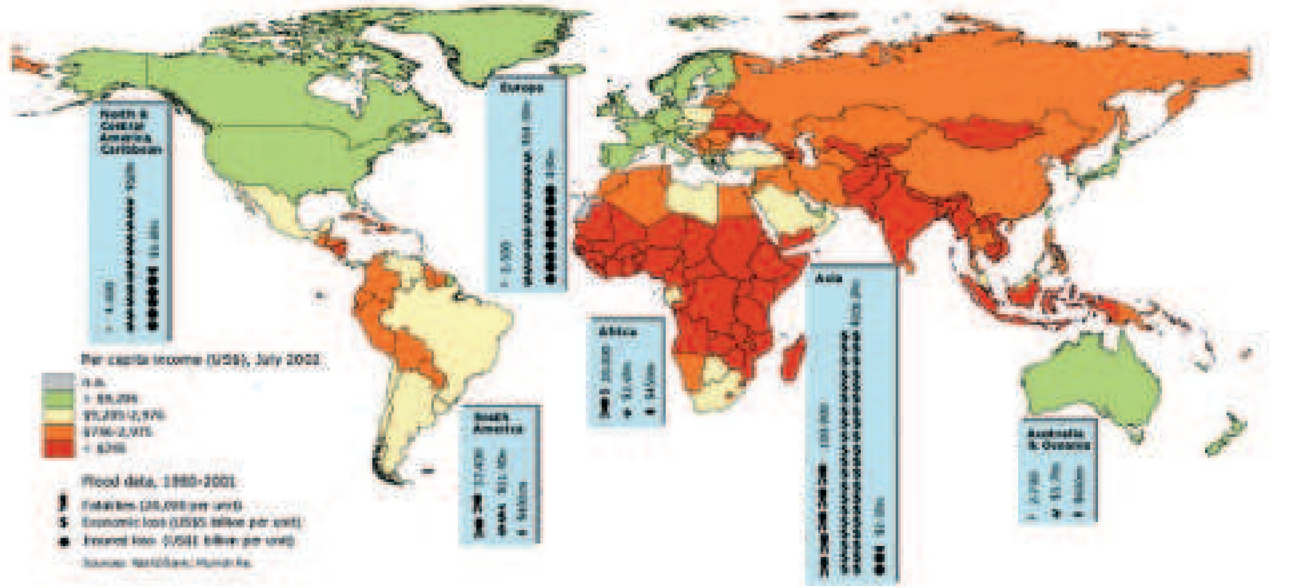


Figure 2.1 *Flood losses, casualties and insured losses (data Munich Re), per capita income (data World Bank). After Bouwer, Kabat at al, (Science, 2003, under review).*

2.1 Effects of climate change on water availability

Using definitions of water scarcity and stress that are described in more detail in Chapter 3, a UN study (UN, 1997) revealed that one-third of the world's total population of 5.7 billion lives under conditions of relative water scarcity and 450 million people are under severe water stress. The UN figures are based on national-level totals, ignoring the fact that, especially in bigger countries, huge spatial differences can occur. Vörösmarty et al. (2000) showed that if these in-country differences are taken into account, four times as many people – 1.8 billion – live in areas with severe water stress. Using their global water model and some projections for climate change, population growth and economic growth, they concluded that the number will have grown to 2.2 billion by the year 2025, and this increase is attributable to a combined effect of population growth with climate change.

Shiklomanov (2003) applies a comprehensive assessment framework to assess the state of the world's water resources[1] . The study focuses not only on the present and future situations, but also includes estimates of water withdrawals and consumption, over the last 100 years (Figure 2.2). In terms of water consumption, the agricultural sector is responsible for 84%, while figures for domestic, industry and reservoirs are 4%, 2% and 10% respectively.

Agriculture has always been the dominant user of water diverted (Figure 2.2). Since 1950, diversions for domestic use and industry have been rising, but they are still low in comparison to agriculture. It is important to recognise that water quality requirements are different for the three sectors and that the impact of shortages on domestic water use will be more critical than for agriculture.

In the same study, Shiklomanov projected water withdrawal and water consumption for each sector in 2025. For agriculture, water withdrawal is projected to rise to 3 200 km^3 and consumption to 2 300 km^3 from respectively 2 600 km^3 and 1 800 km^3 in year 2000. Total withdrawal for all sectors is projected to be almost 5 500 km^3, compared with less than 4 000 km^3 in 2000.

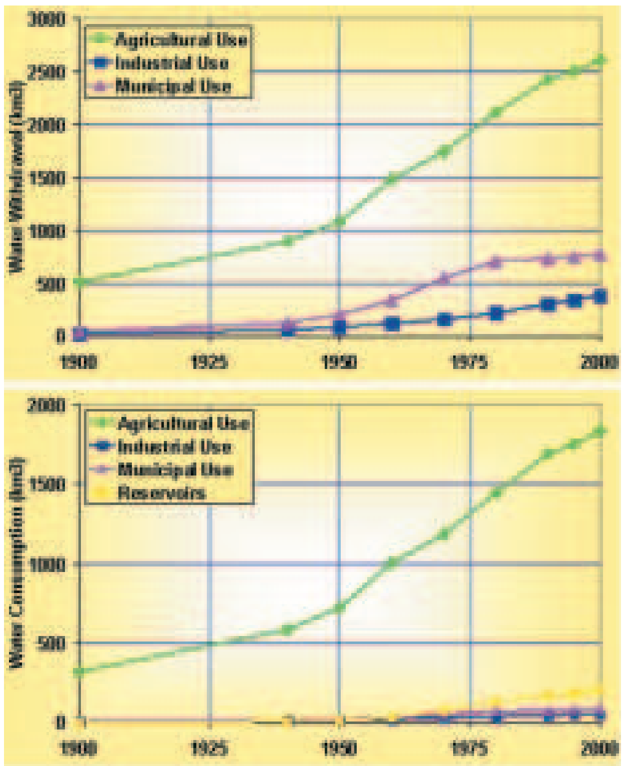


Figure 2.2 *Dynamics of water withdrawals (top) and consumption (bottom) per sector. Source: Shiklomanov, 2003.*

[1] (http://webworld.unesco.org/water/ihp/db/shiklomanov/)

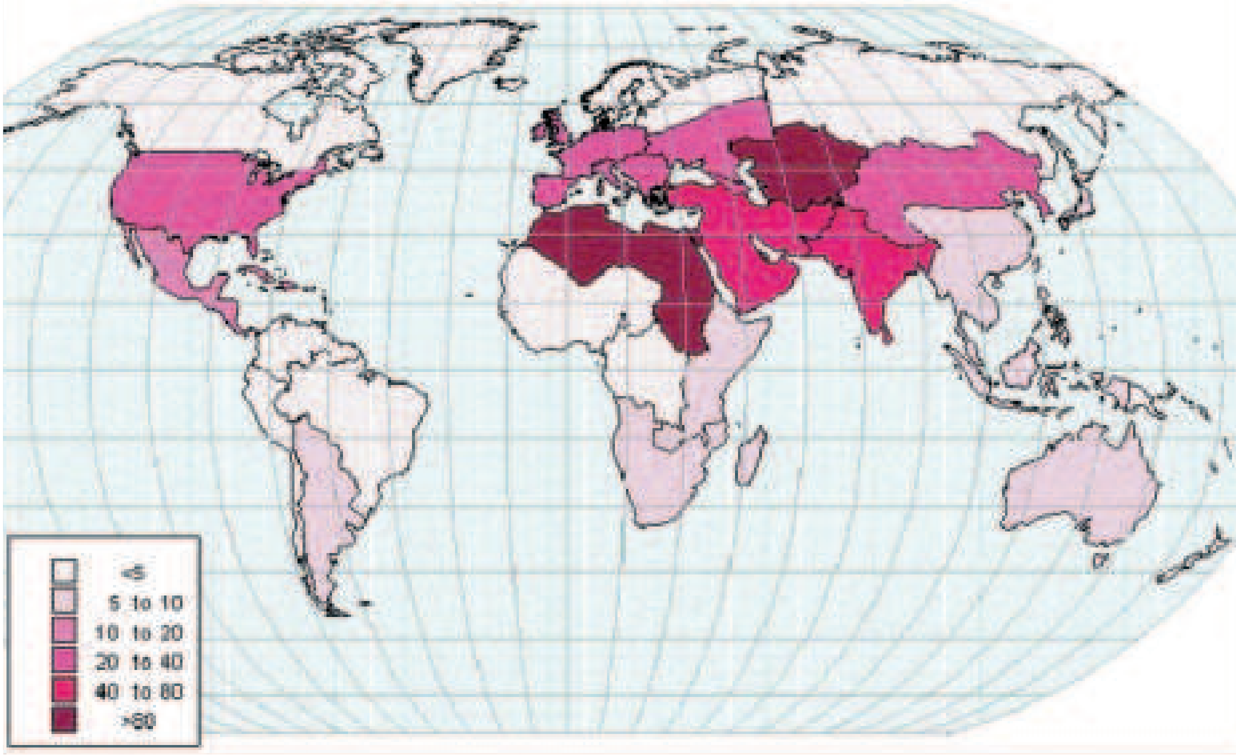


Figure 2.3 *Percent of water consumption from total water resources by natural-economic regions of the world in 2000. Source: Shiklomanov, 2003*

In terms of spatial distribution, the dryer regions in the northern hemisphere already consume a very high proportion of their water resources (Figure 2.3). It is alarming that population growth is expected to be very high in these regions, particularly China, India and Pakistan.

It is also interesting to put the above figures and estimates on future demands in the context of the world's available water resources. Rodda (2001) presents "Scenarios for World Water Resources and Demands", in which estimates of world water resources are compared with global demand for water (Fig.2.4). Starting at a lower range of the estimates of available world water resources of about 25 000 km^3 per year, this study shows that in 2000, almost 5000 km^3 of available water was already lost due to pollution, and this loss will continue to occur at an increasing pace. In about the year 2040, progressively increasing global water demand (middle scenario in Fig 2.4) will meet the decreasing curve of water availability (corrected for pollution losses) at roughly 12 000 km^3. From there on, the global demand is projected to exceed the availability. In these projections no impacts of climate have been considered.

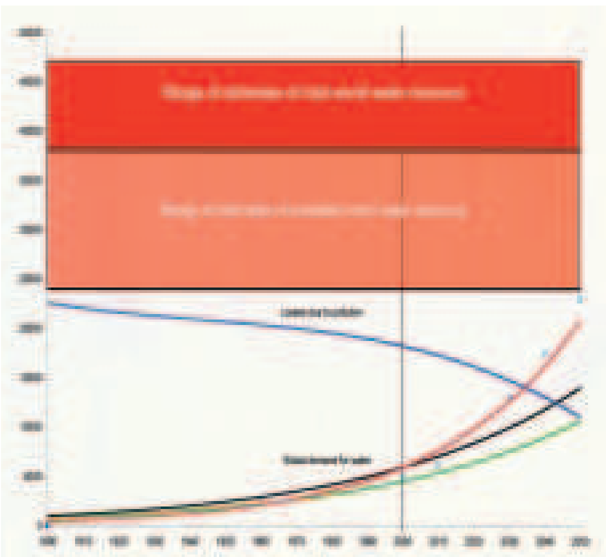


Figure 2.4 *. "Scenarios for World Water Resources and Demands", in which estimates of world water resources are compared with global demand for water. After Rodda, 2001.*

Chapter 1 has several examples of how climate change may impact on water resources availability at global scale, with some examples of regions where the present water scarcity is expected to be exacerbated by climate change.

While some regions of the world may benefit from climate change, the majority of the global impacts are expected to be adverse. Using the concept of 'water stress' (see Box 3.2 in Chapter 3), one can compare the average state of water resources around the world. In Figure 2.5, this analysis has been done for the year 1995. It shows that nearly a quarter of the world's terrestrial surface (excluding the ice caps) is in the severe stress category, including most of India, northern China, Middle Asia, the Middle East, northern and southern Africa, parts of southern Europe, western Latin America, a large part of the western United States, northern Mexico, and a few drainage basins in Australia (Alcamo et al., 2002).

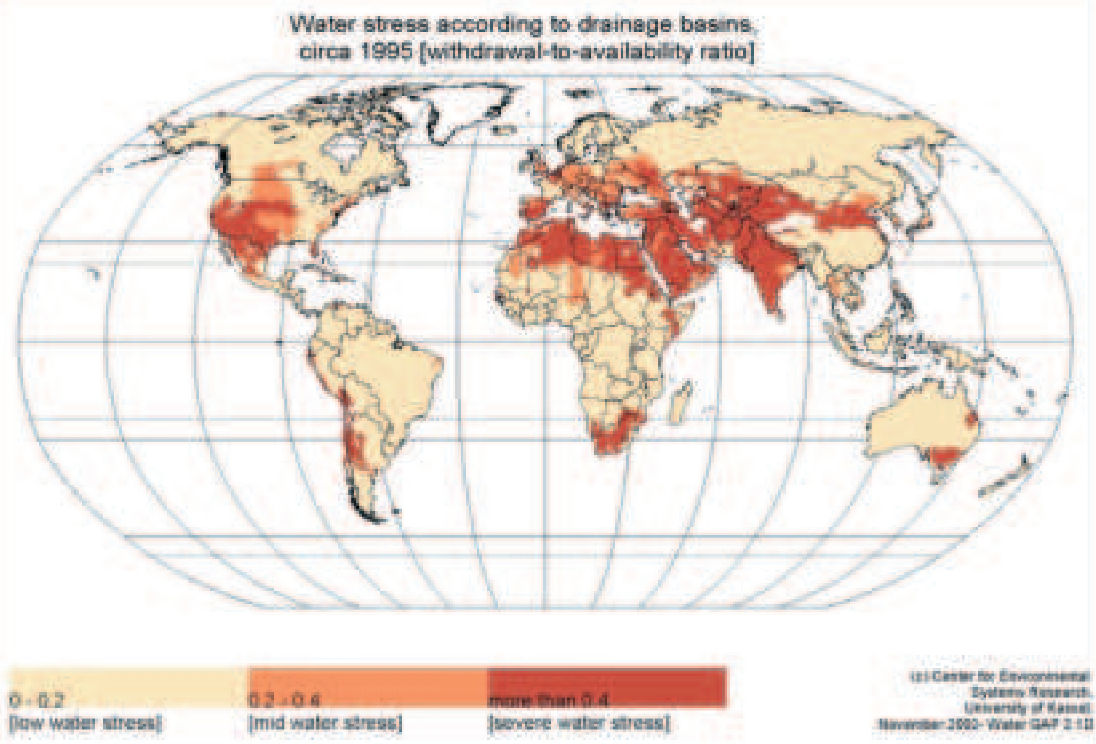


Figure 2.5 *Water withdrawal to availability ratio (water stress index) in the year 1995 (Alcamo et al., 2002)*

To assess the future situation of water stress, the ‘withdrawals to availability ratio’ (w.t.a) was calculated for the IPCC SRES A2 and B2 scenarios (see Chapter 1, Section 1.5.3) with both climate data sets and for two time horizons – 2025 and 2075. Figure 2.6 is an example of this analysis. The situation illustrated is the 2020s using the A2 scenario and the HadCM3 climate data set.

The areas under water stress are slightly increased compared with the 1995 situation. Additional areas under water stress can be identified in the eastern parts of Poland, northeastern and southeastern parts of China, the southern Nile basin, and around Lake Victoria (Tanzania, Uganda, Kenya, Rwanda and Burundi). In southern Africa, the Kunene basin at the border of Namibia and Angola will have severe water

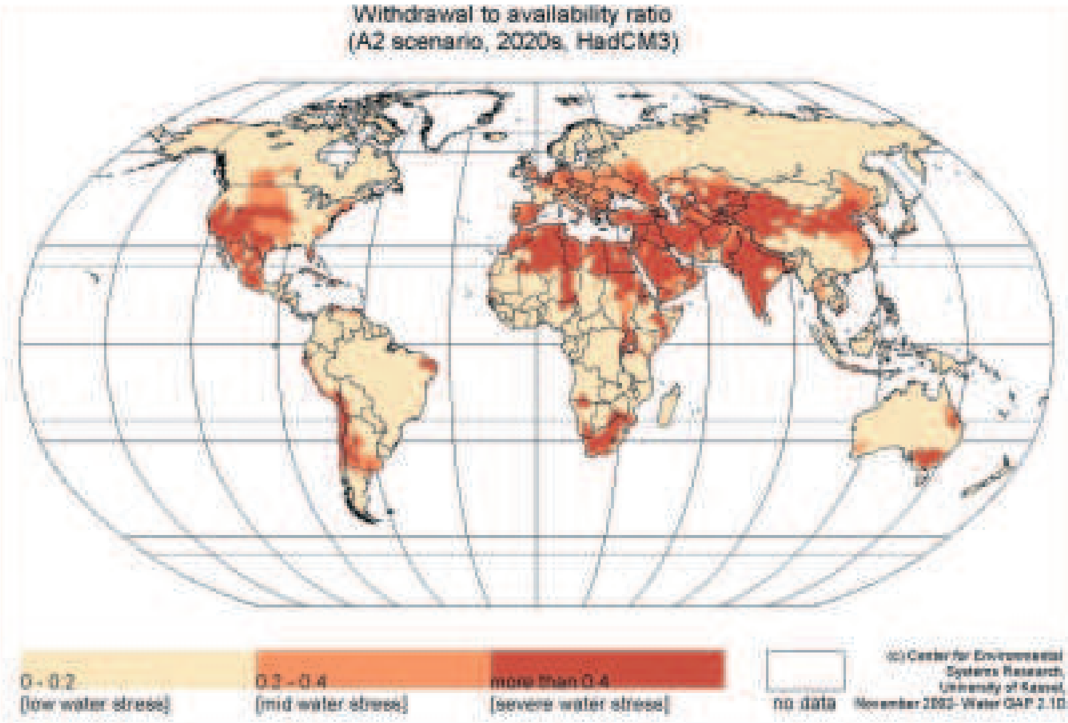


Figure 2.6 *Water to availability ratio (water stress index) in the 2020’s as a result of combined effects of climate change and socio-economical development (Alcamo et al., 2002)*

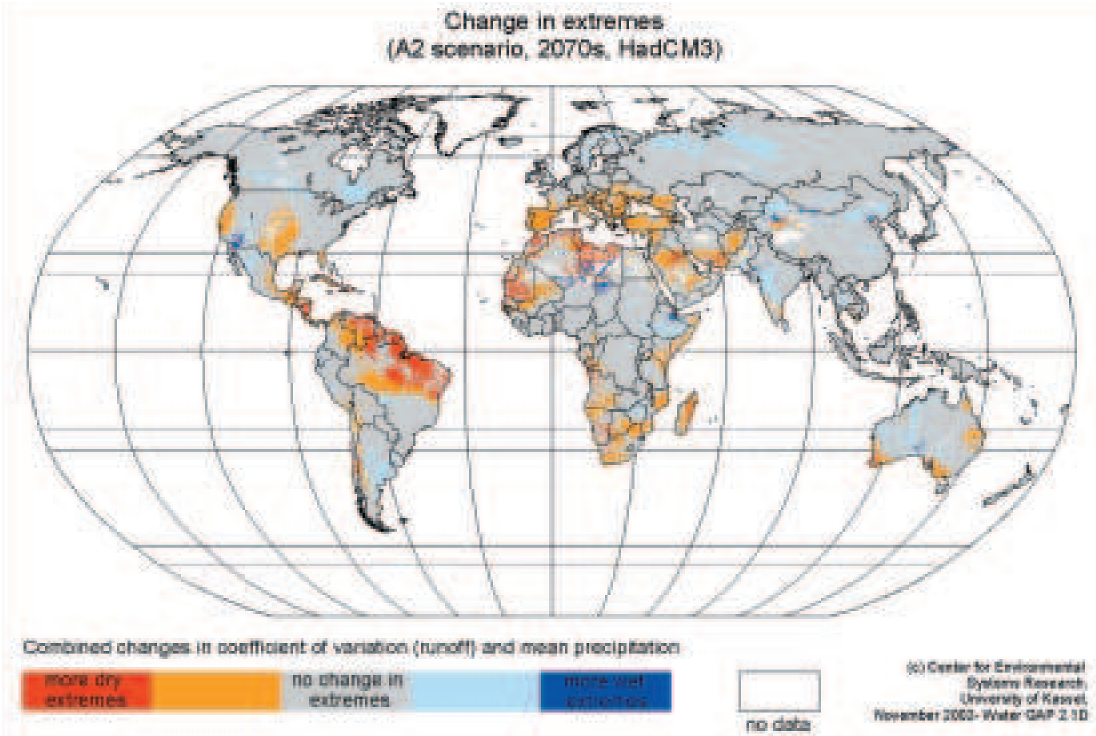


Figure 2.7 *Changes in extreme event frequency in the 2070s (Alcamo et al., 2002)*

stress. Water stress is shown also for the Perth area of Australia. In Latin America, eastern parts of Brazil and areas south of Buenos Aires in Argentina will have water stress, as well as large parts of central Mexico.

It is not only average annual water availability that will be affected by climate change. The frequency of extreme climate events and inter-annual variations in rainfall and river flows are both predicted to rise in critical areas. Figure 2.7 shows that many currently humid regions (such as Northern Europe) will have even higher and more frequent peak river discharges. It also shows that current arid areas (e.g. Turkey, Northeast Brazil and southern Africa) will experience more frequent low flow conditions.

Figure 2.8 shows changes in annual river discharges comparing the hydrological year October 1982 -

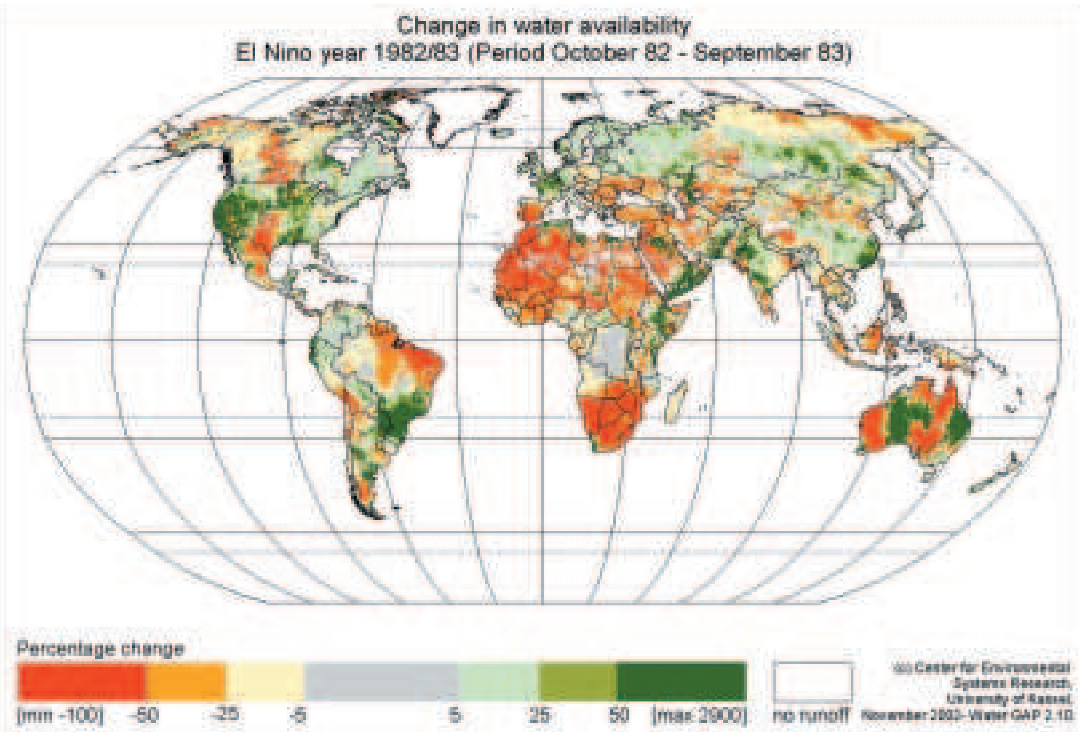


Figure 2.8 *Changes in water availability for the El Niño event 1982/3 (Alcamo et al., 2002)*

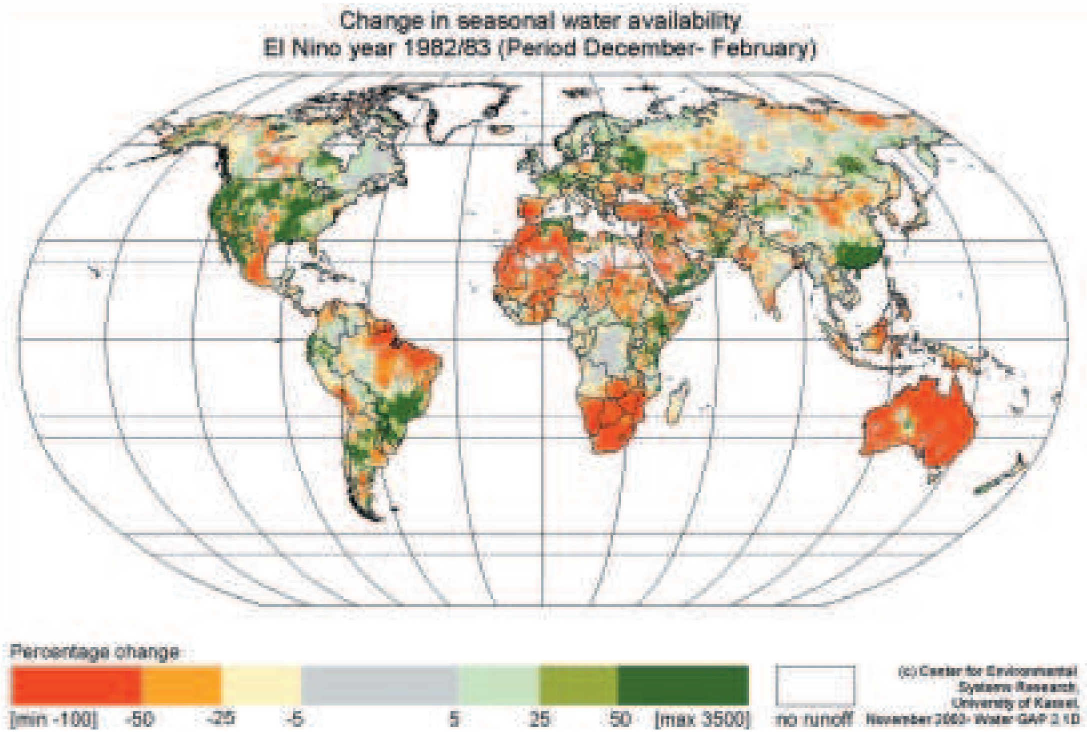


***Figure 2.9** Changes in water availability for the El Niño period December 1982 –February 1983 (Alcamo et al., 2002)*

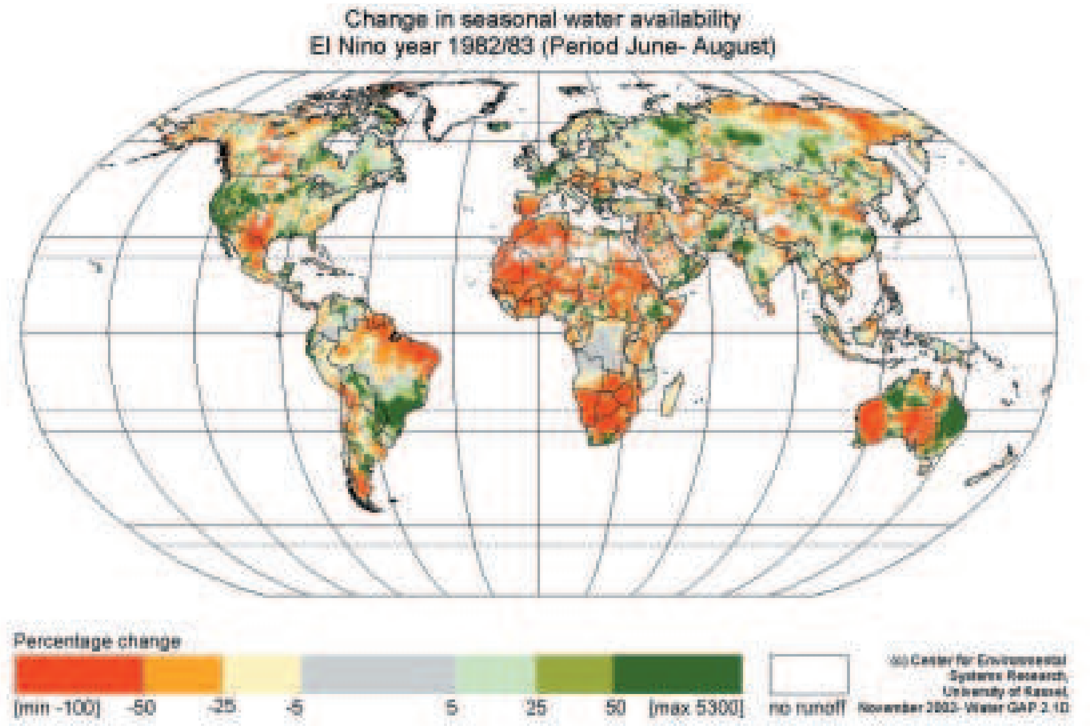


***Figure 2.10** Changes in water availability for the El Niño period June- August 1983 (Alcamo et al., 2002)*

September 1983, which is known as one of the most devastating El-Nino years (see Chapter 1, Section 1.3.2), with the thirty-year average of the period 1961-1990 (Alcamo et al., 2002). Since El Niño is strongly related to seasonal changes in precipitation and temperature patterns, it is interesting to compare maps for the warm period December 1982 –February 1983 with those for June-August 1983 (Figures 2.9 and 2.10). The discharges shown in Figure 2.8 for the warm period correspond widely with typical global temperature and precipitation patterns during El Niño situations. Extreme dry conditions are modelled for the northeastern part of Latin America, southern Africa, Indonesia and Australia. Extreme wet conditions occur in southern China, southern Brazil, western parts of central Argentina, Ecuador, northern Peru and the Mississippi basin, as well as the west coast of the US. In the period of El Niño (June – August 1983), the general situation is drier, except for the east Andean region and the western US, which show wet extremes (Figure 2.10).

Climatic impacts on water resource availability and the frequency of extreme events will have both direct and indirect consequences for human health, sanitation, nature and ecosystems, agriculture and hydropower generation.

2.2 Water, health and sanitation

Water is essential for human health and for many people, especially the urban and rural poor in developing countries, one of the greatest threats to health remains a lack of clean water and sanitation. A recent report (WHO/UNICEF 2000) revealed that some 2.4 billion live without access to proper sanitation. One billion have no access to safe water. This is an important factor in the enormous global burden of diarrhoeal illness and early childhood mortality. Approximately 5,000 children die every day from water-related illnesses.

Figure 2.11, from the WHO/UNICEF report shows that urban water supply and sanitation coverage is significantly higher in most regions than rural coverage. Furthermore, rural coverage tends to be far more variable between regions than urban coverage. For example, urban water supply coverage in 2000 varies only from 85% in Africa to 100% in Europe and northern America, while rural water supply coverage varies from 47% in Africa to 100% in northern America. Interregional variations are most stark for rural sanitation, with Asia having only 31% coverage, while northern America has 100% coverage. While rural populations generally have a lower access level to both water supply and sanitation, megacities face special challenges in keeping up with rapidly increasing population levels and a changing climate.

Both long term climate changes and shorter-term increases in climate variability have an impact on the water resources and on the efficacy of water supply and sanitation systems. If water supplies become more water stressed (cf. Figure 2.6), this could reduce the water available for drinking and hygiene. It could also lower the efficiency of local sewer systems, leading to higher concentrations of bacteria and other micro-organisms in raw water supplies. Falling groundwater levels can leave shallow hand pumps high and dry and force people to use poorer quality water sources, such as contaminated rivers. All these factors are likely to result in an increased incidence of diarrhoeal diseases.

Climate change is likely to lead to health impacts that encompass direct and indirect, immediate and delayed effects (McMichael and Haines, 1997). The climatic changes that would specifically affect water resources and hence human health are summarised in Table 2.1. Some health outcomes in some populations would be beneficial: for example, winter cold-snaps are expected to become milder in temperate-zone countries where death rates typically peak in winter time. However, most of the anticipated health effects are adverse, and it is expected that these will fall disproportionately on the poor (IPCC, 2001).

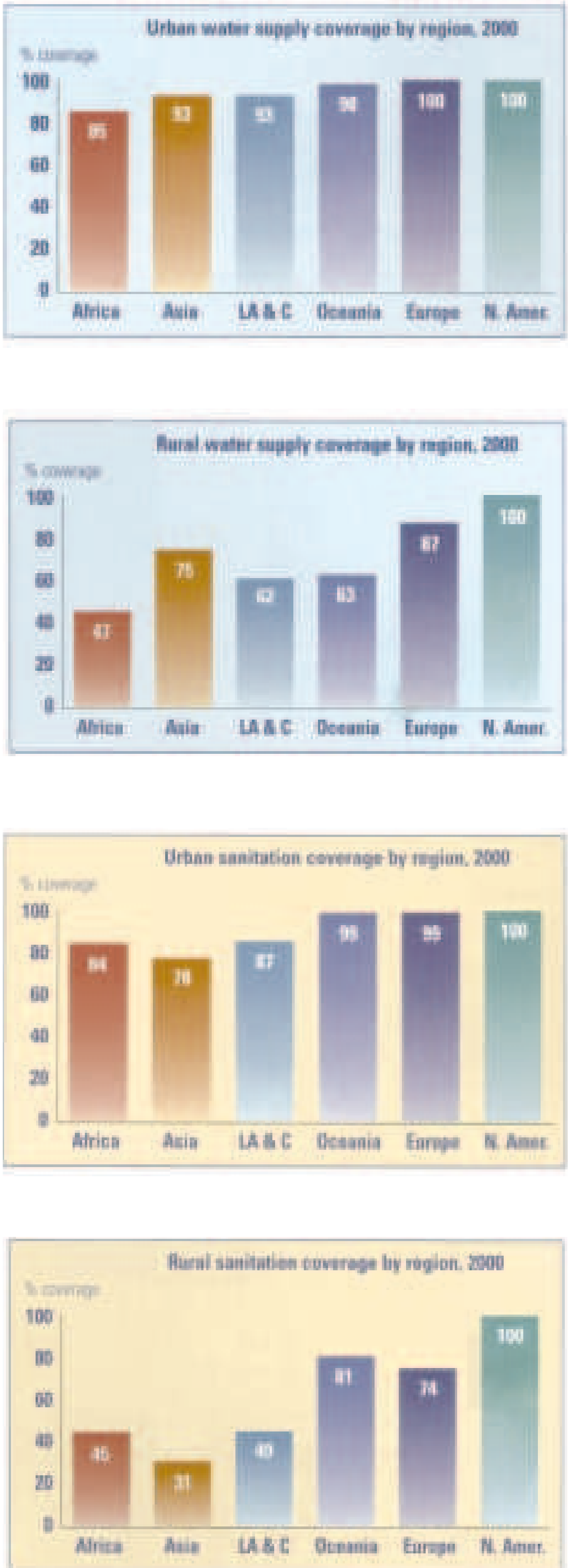


Figure 2.11 *Urban and rural water supply and sanitation coverage by region (WHO, 2000)*

Mediating processes	Health outcome
Direct effects	
Change in the frequency or intensity of extreme weather events, for example storms, hurricanes, cyclones	Deaths, injuries, psychological disorders; damage to public health infrastructure
Indirect effects	
Changed local ecology of water borne and food borne infective agents	Changed incidence of diarrhoeal and other infectious diseases
Changed food productivity (especially crops) through changes in climate and associated pests and diseases	Malnutrition and hunger, and consequent impairment of child growth and development
Sea level rise with population displacement and damage to infrastructure	Increased risk of infectious disease, psychological disorders
Social, economic, and demographic dislocation through effects on economy, infrastructure, and resource supply	Wide range of public health consequences: mental health and nutritional impairment, infectious diseases, civil strife

Table 2.1 *Mediating processes and direct and indirect potential effects on health of changes in temperature and weather (Source: Adapted from McMichael and Haines 1997)*

The indirect effects of climate change on human health are substantial. This is a direct result of the many ways in which water can act as a player in disease transmission (see Box 2.1). Through indirect pathways, the health threats of climate change include malnutrition arising from agricultural disruption, infectious diseases spread by insects and other vectors advantaged by climate change, as well as the increased risk of infectious diseases due to infrastructure damage.

Box 2.1 The role of water in disease transmission.

There are several ways in which water is involved in transmission of disease:

- Water-borne diseases result from the contamination of water by human or animal faeces, or by urine infected by pathogenic viruses or bacteria, in which case the disease is transmitted directly when the water is drunk or used in the preparation of food.
- Water-washed diseases are those resulting from inadequate personal hygiene because of scarcity or inaccessibility of water. These include many water-borne diseases as well as typhus.
- Water-based diseases are those arising from parasites that use an intermediate host that lives in or near water (e.g. guinea worm).
- Water-related diseases are diseases borne by insect vectors which have habitats in or near water (e.g. malaria).
- Water-dispersed diseases are infections whose agents proliferate in fresh water and enter the human body through the respiratory tract (e.g. Legionella).

2.2.1 Vector-borne diseases

Anticipated changes in temperature, precipitation, humidity and wind patterns will directly affect vector species reproduction, development and longevity. Climate plays an important role in the geographical distribution and seasonal abundance of these vector

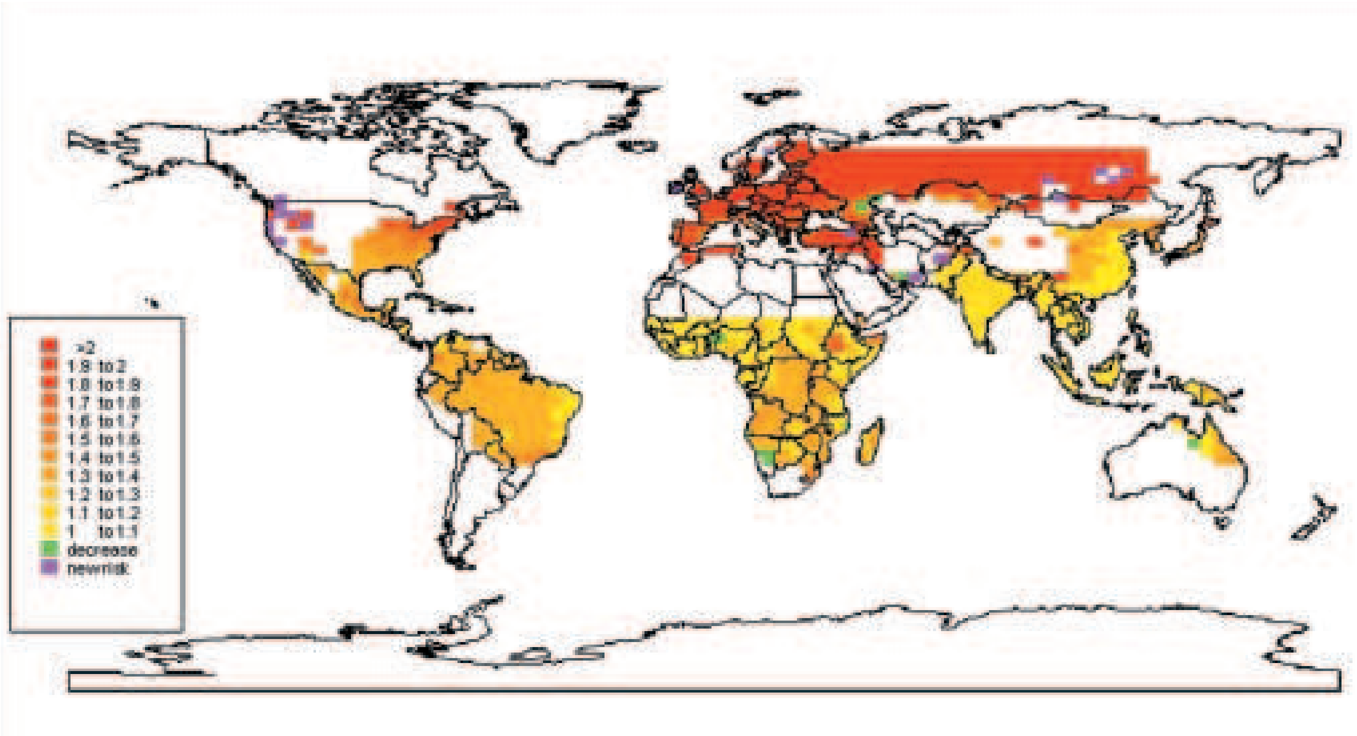


Figure 2.12 *Potential malaria transmission changes for the 2020s based on the HadCM3 climate change scenario (Martens et al., 1999)*

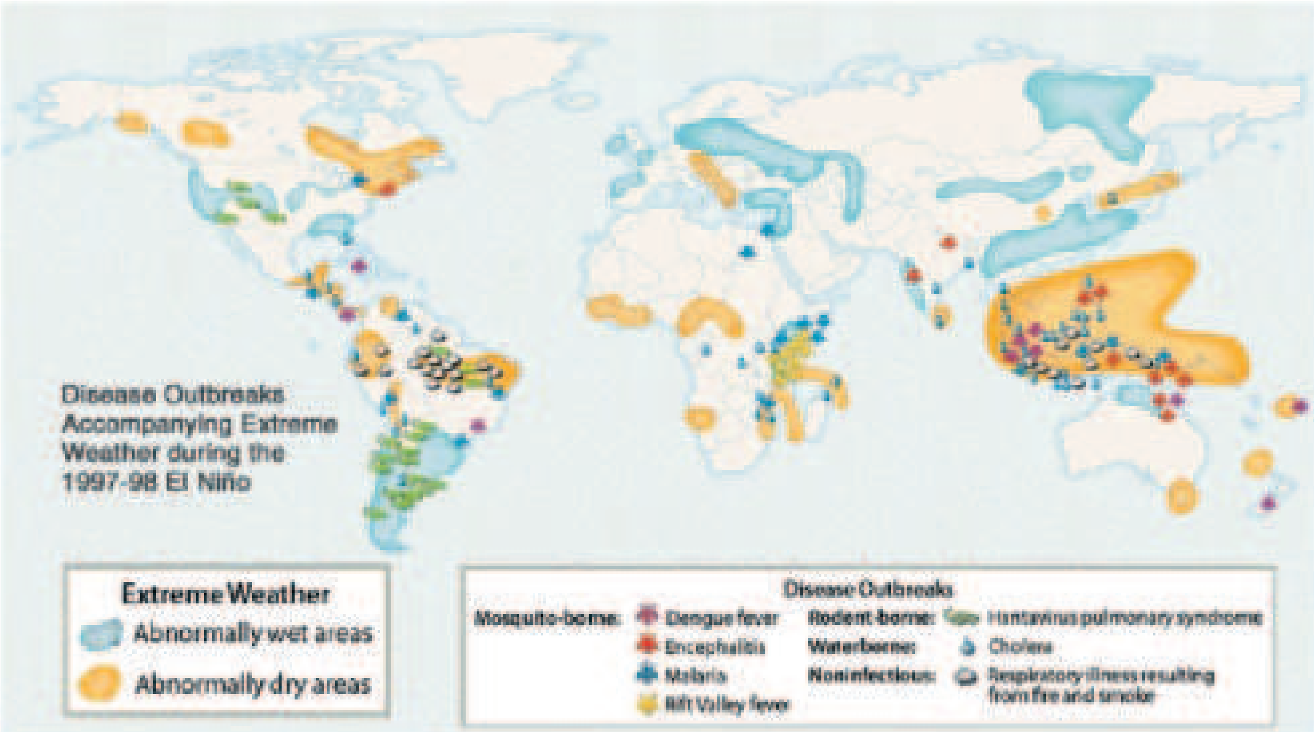


Figure 2.13 *Disease outbreaks which accompanied extreme weather during the 1997-98 El Nino*
(Source: The Centre for Health and the Global Environment, Harvard University)

species. The distribution of vector-borne diseases in the human population is also limited by temperature in many regions where the climate is too cold for the parasite to complete its development in the insect host and be transmitted to people (Martens et al., 1999). In addition, persistence of water in low-lying areas creates breeding grounds for mosquitoes with increased risk of malaria, yellow fever and Dengue.

Martens et al. (1999) analysed the global implications of climate change in terms of future populations at risk of contracting malaria. The greatest proportional changes in potential transmission are forecast to occur in temperate zones, in areas where vectors are present but it is currently too cold for transmission. Figure 2.12 shows the potential malaria transmission changes (*P. vivax*) for the 2020s due to climate change, compared with the baseline.

The map indicates higher potential malaria transmission rates over large parts of the world, including new regions in the US, Canada, and scattered areas in the Soviet Republic and the Middle East. The impacts of higher transmission rates, and introduction of the disease into new areas can be particularly severe in regions with low adaptive capacity.

2.2.2 Climate extremes, water and health

Examination of the relationship of disease outbreaks to extreme weather associated with the 1997-8 El Niño shows the type of impacts that may occur due to increased climate variability. Direct impacts on health were observed in several areas, including the Pacific islands, and scientists have linked El Niño with illnesses such as malaria, cholera and Dengue fever, as shown in Figure 2.13

The direct health effects on the water sector of related extreme events such as floods and droughts include changes in mortality and morbidity. They are primarily due to the physical hazards of the increased occurrence of extreme events. The consequences of more frequent extreme events translate into real losses – livelihoods and lives.

2.2.3 Floods and health

Different pressures have combined to increase population densities in flood-prone areas, including shortage of land which has caused encroachment into floodplains. In particular, there has been mushrooming of informal settlements in endangered zones and around mega-cities in developing countries as people migrate towards economically developed city centres. The hope of overcoming poverty drives poor people to migrate, frequently into places vulnerable to flooding and where effective flood protection is not assured.

Beyond the immediate direct effects, floods can have a variety of indirect impacts on human health (Few, 2002):

- Physical threats from flowing water
- Overburdening of wastewater and sewer systems, leading to contamination of water supplies with resulting outbreaks of dysentery and cholera
- Disruption of safe water supplies

- Persistence of water in low-lying areas creating breeding grounds for mosquitoes with increased risk of malaria, yellow fever and Dengue
- Floods may also expose individuals to respiratory infections and skin allergies
- Disruption to medical facilities and the increased demand on their resources can reduce people's access to necessary treatment and medicine
- Potential mental health impacts resulting from stress, e.g. as a result of forced displacement, loss of home and/or family
- Impact of inadequate nutrition following disruption to incomes and food distribution systems.

2.2.5 Droughts and health

Desertification and droughts have complex linkages with climate change and human health, as illustrated in Figure 2.14. There are some difficulties in quantifying their impacts, as there is not a consensus of opinion on how both terms should be defined. Even without agreement on the terms, it is clear that both desertification and droughts have important implications for the management of water resources, and these in turn have important consequences for human health.

Droughts have several direct and indirect impacts on human livelihoods. A direct consequence of drought is crop loss which can, in turn, cause starvation among humans if alternative food sources are not available. Indirectly, water shortage contributes to the proliferation of diseases, as people lack water for basic hygiene. If a drought persists, people are often forced to migrate and there are evident multiple health problems in refugee camps.

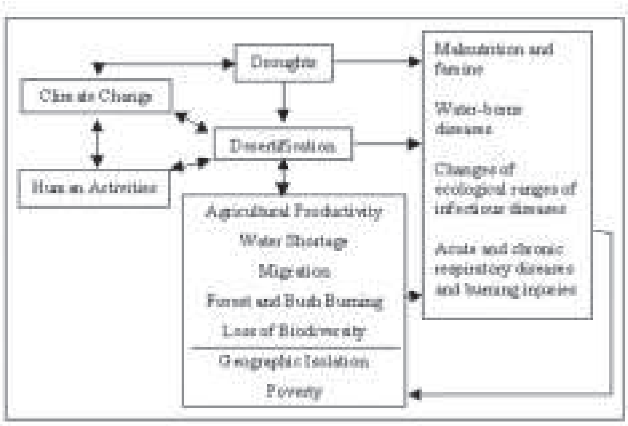


Figure 2.14 *Climate change, droughts and desertification: The linkages with human health. (Menne and Bertollini, 2000)*

2.3 Water, climate and food security

Guaranteeing sufficient food to sustain the growing world population is one of the key challenges now and in coming decades. According to a recent FAO study, about 800 million people in the developing world do not have enough to eat (FAO, 2002a). Another 41 million people in the industrialised countries and countries in transition also suffer from chronic food insecurity. Although food production is still on the rise, increases are mainly in the developed world, where production subsidies play an important role (Figure 2.15).

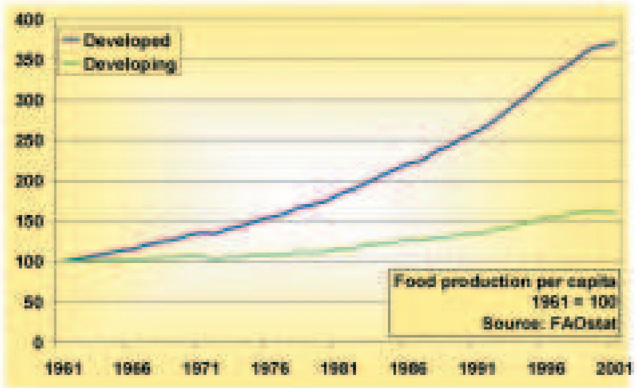
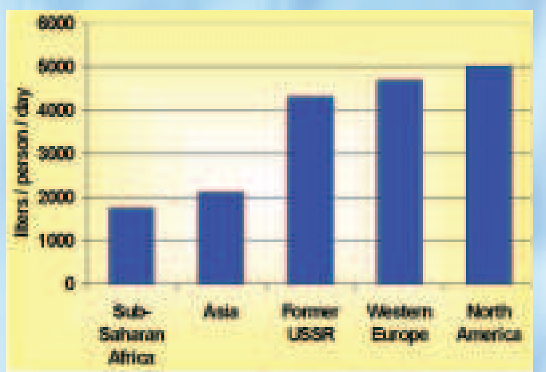


Figure 2.15 *Global trends in food production over the last 40 years expressed as food produced per capita. Depicted figures are indexed with the period 1961 set as 100.*

BOX 2.2. How much water do we eat?



Source: Gleick, P.H. 2000. The World's Water 2000-2001. The Biennial Report on Freshwater Resources. Island Press. Washington D.C. and Covelo, California

The average person needs a minimum of 5 litres of water per day to survive in a moderate climate at an average activity level. The minimum amount of water needed for drinking, cooking, bathing, and sanitation is 50 litres. However, the average person in the United States uses between 250 and 300 litres per day for drinking, cooking, bathing, and watering their yard.

Besides this direct water requirement, a substantial amount of water is used to grow our food. A hectare of wheat might consume between 5 and 15 million litres of water, depending on climatic conditions and agronomic practice.

The amount of water required to produce a slice of bread is about 40 litres, a cup of yogurt 300 litres, and a hamburger about 2 300 litres.

The total of amount of water a person "eats" is a function of what is actually eaten, how much, and where this food has been produced. Differences between regions can be substantial.

According to the latest estimates in FAO's AQUASTAT, about 10% of all crops are irrigated, while 43% of the global grain production originates from irrigated lands (FAO, 2002b). The same source indicates that from all water diverted, 62% is used for irrigation and 21% and 17% for domestic use and industry, respectively. Note that the data are based on withdrawals and not on consumption.

The question as to whether water resources will be sufficient to feed the world's people and at the same time sustain the environment is in reality many questions with many uncertainties and subjectivity. According to Gleick (2002) a set of questions should be answered to address the main question of food security, such as how many people, what and how much will they eat, future crop yields, land quality and availability, irrigation and rainfed areas, etc. The number of uncertainties in most of these questions is substantial and it is therefore no surprise that many different estimates have been presented on whether sufficient food can be produced and what the consequences on water resources are.

As an example, Seckler et al. (1999) estimated that by 2025 cereal production will have to increase by 38% to meet world food demands. The World Water Vision, an outcome of the Second World Water Forum in The Hague in 2000, estimated a similar figure of 40% based on various projections and modelling exercises (Cosgrove and Rijsberman, 2000). Adopting UN mid-range 2025 population estimates of 8.9 billion people combined with the minimum caloric requirement of 2,200 calories per day, means that a total of about 20 trillion consumable calories have to be produced. Current levels are about 14 trillion calories which means an increase of 42%. However, given the range in population estimates as provided by the UN this figure can be between 14 and 71%.

It is obvious that the question of whether we will be able to produce sufficient food is associated with many uncertainties. On top of these uncertainties will be the impact of climate change and increased climate variability, including extremes.

2.3.1 Climate change impacts on crop growth

Besides the obvious impact of changes in precipitation, which result in changes in soil moisture conditions, two other components related to climate change are important in terms of crop production: increased CO_2 levels and higher temperatures.

Crop production is affected by atmospheric CO_2 levels. Photosynthetically Active Radiation (PAR) is used by the plant as energy in the photosynthesis process to convert CO_2 into biomass. Scientists make a distinction between C3 and C4 plants. Examples of C3 plants are potato, sugarbeet, wheat, barley, rice, and most trees except mangrove. C4 plants are mainly found in the tropical regions and some examples are millet, maize, and sugarcane. A third category are the so-called CAM plants (Crassulacean Acid Metabolism) which have an optional C3 or C4 pathway of photosynthesis, depending on conditions: examples are cassava, pineapple, and, onions.

The difference between C3 and C4 plants is the way that carbon fixation takes place. C4 plants are more efficient in this and in particular the loss of carbon during the photorespiration process is negligible for C4 plants. C3 plants may lose up to 50% of their recently-fixed carbon through photorespiration. This difference has suggested that C4 plants will not respond positively to rising levels of atmospheric CO_2. However, it has been shown that atmospheric CO_2 enrichment can, and does, elicit substantial photosynthetic enhancements in C3 species (Wand et al., 1999). This means that C3 plants (potato, sugar beet, wheat, barley, rice, etc.) may well profit from higher atmospheric CO_2.

Higher temperatures are associated in general with higher radiation and higher water use. It is relatively difficult to separate the physiological effects (at the level of plants and plant organs) of temperatures from the ecological ones (at the level of the field or of the region). There are both positive and negative impacts at the two levels.

At the plant level it is expected that rising temperatures would diminish the yields of some crops, especially if night temperatures are higher (Kukla and Karl, 1993). However, some positive effect on crop growth can also be expected unless plants get overheated. On a regional scale, higher temperatures will promote more plant growth at high latitudes and altitudes. It is expected that the effect of enhancing crop yields will occur in the northern regions of the former Soviet Union, Canada, and Europe. The predicted yield increases in these higher latitude regions are due primarily to a lengthening of the growing season and the mitigation of negative cold weather effects on plant growth (Rosenzweig and Parry, 1993). On the other hand, negative effects on crop and livestock productivity are expected in northern middle latitude countries like the U.S., Western Europe, and most of Canada's currently productive agricultural regions. This is due to a shortening of the growing period for the plant caused by a increased temperature and increased evapotranspiration rates (Tobey et al., 1992)

2.3.2 Climate variability and prolonged dry spells

While climate change may still occur gradually over a longer time scale, extreme events are being enhanced faster – and they are very difficult to cope with in the context of food production. These extremes include an increase of successive years with droughts or floods, which is especially difficult for farmers (Figure 2. 16). A farmer can survive a less productive year if followed by a normal year, but two or more less productive years are hard to survive.

2.3.3 *Contrasting global projections*

Several global (modelling) studies have been published recently on food security in the future. A study by FAO (2002c) claims that in the next three decades, climate change is not expected to depress global food availability, but it may increase the dependence of developing countries on food imports and accentuate food insecurity for vulnerable groups and countries. In terms of water requirements the projections for developing countries indicate that a 14% increase is expected in water withdrawals for irrigation by 2030.

In contrast to these figures, results presented by the International Food Policy Research Institute (Rosegrant et al., 2002) show that the increase in irrigation water will be only 4%, mainly as a result of water shortages.

The International Institute for Applied Systems Analysis presented a study based on their GAEZ approach (Global Agro-Ecological Zoning), indicating that the impacts of climate change on crop production are geographically unevenly distributed (Fischer et al., 2002). The UN Millenium Development Goal of eradicating extreme poverty and hunger, has a specific target of halving the proportion of people living on less than a dollar a day and suffering from hunger by the year 2015. Results from Fischer et al. (2002) show that for IPCC SRES scenarios A1, B1, A2, and B2, (see Chapter 1, Section 1.5.3) and without consideration of the impacts of climate change, there is little progress in reducing hunger up to 2020, in spite of relatively high levels of economic growth. The results imply that specific targeted programs for hunger reduction will be necessary to meet the millennium goals of reducing hunger by half in 2015. However, if climate change is included, the result is an increase the number of people at risk of hunger by 2080.

For rain-fed cereal production potential, based on four HADCM3 climate change scenarios, the estimated impacts on current cultivated land imply that there are 42-73 countries with potential cereal declines of more than 5%, and 54-71 countries whose production potential is expected to increase (see Figure 2.17)

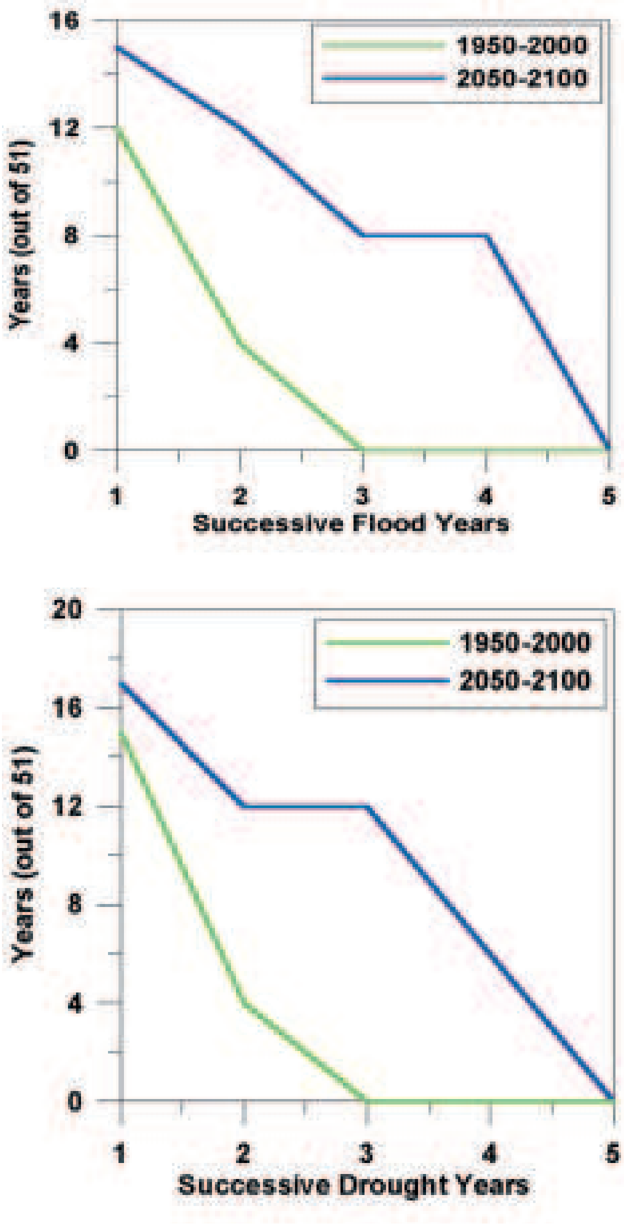


Figure 2.16 *Increase in successive years of droughts and floods for Zayandeh Rud Basin in Iran for the current situation and the Hadley A2 climate change projection.*

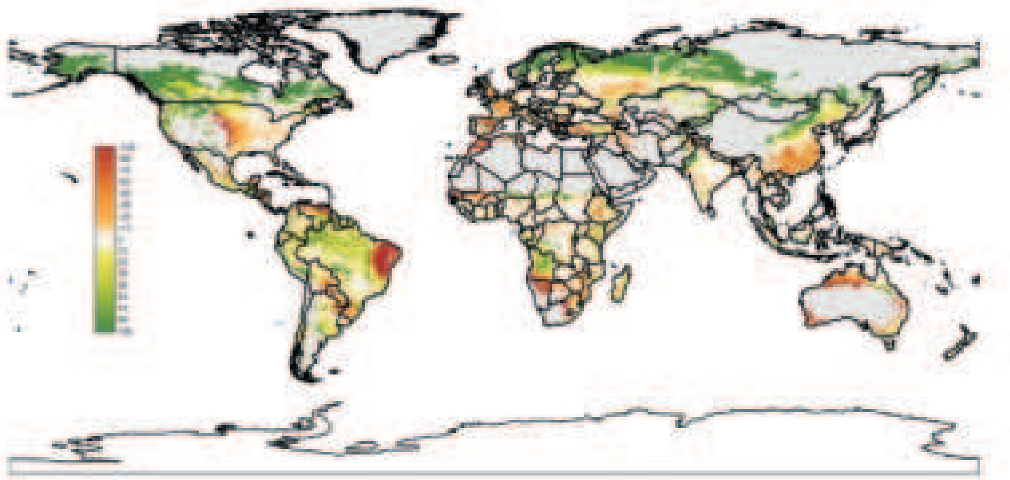


Figure 2.17 *Climate change implications for rain-fed cereals (Had3-A1FI, 2080s) (Fischer et al., 2002)*

These impacts would be of global significance if imposed on an already high level of under-nourishment, as is the case in the assumed development scenario A2. In all other scenarios, with rapid economic growth and a transition to stable population levels, poverty, and with it hunger – though negatively affected by climate change – would become a less prevalent phenomenon than it is today.

2.3.4 Food market imbalances due to climate change

Shortfalls in food production caused by climate variability and change create market imbalances, which push international prices upwards and provide incentives for reallocation of capital and human resources, thus reducing climate-change impacts by economic adjustments. The result of the impacts of climate change on GDP of the agricultural sector is that in the developing regions, with the exception of Latin America, it will be negatively impacted (Fischer et al., 2002). Since high-tech solutions do not always reach and are not always tailored to meet the needs of the poorer farmers, who are often reliant on rain for crop sustenance, it will again probably be the poor who pay the highest price.

Simulations of the IPCC – SRES development path scenarios without climate change result in a growing dependence of developing countries on net cereal imports of between 170 million tons (scenario B1) and 430 million tons (scenario A2). Climate change will add to this dependence, increasing net cereal imports of developing regions by 10–40% according to development path scenario and GCM climate projections. Even in the case of projections resulting in overall positive impacts on agricultural productivity, the comparative advantage for producing cereals shifts to developed countries, and net imports of developing countries increase by about 25%, an additional 110 million tons in scenario A2 and around 90 million tons of additional cereal imports in scenario B2 (Fischer et al., 2002).

2.4 Water, climate and nature

The concept of freshwater should not be reduced to that of a mineral flowing through channels, canals and pipes. Freshwater is an essential driver of terrestrial and aquatic ecosystems. Any state of equilibrium in the distribution of terrestrial ecosystems results from a balance between climatic conditions and the resilience of the systems to variations in those climatic conditions. A change in the variability of climate, or a trend in any one of its components, may lead to latitudinal and altitudinal shifts in the distribution of terrestrial ecosystems (e.g. rainforests, savannas, steppes). In a given watershed (also termed catchment or basin), these changes might have tangible effects on the water budget and thus on the availability of water resources.

Freshwater ecosystems (such as ponds, lakes, wetlands and rivers channels) are essential components of the environment. They provide support for the existence of aquatic and terrestrial wildlife, environmental goods (e.g. water, foods) and services (such as flood attenuation,

Box 2.3 The importance of the environment in water resources.

With a water crisis facing many countries, it seems an immense task just to manage water so that there is enough for domestic supply, agricultural and industrial uses. Providing water for other uses, such as the 'environment' is often given a low priority. Indeed, the situation is often presented as a conflict of competing demand, as though it was a matter of choice between water for people and water for wildlife. However, since the UNCED Conference in Rio in 1992, it has been recognised that the 'environment' means far more than just wildlife, although the need to conserve biodiversity is widely accepted. Functioning ecosystems perform vital functions such as flood reduction, groundwater recharge and low flow augmentation, and important products, such as fish, pastureland, reeds, medicines and timber (Acreman, 1998). Thus for the millions of people worldwide, particularly the rural poor, who depend directly on natural resources or benefit from ecosystems, providing water for the environment and for people is one and the same (Acreman, 2001).

The Dublin Conference in 1992 (a preparatory meeting for UNCED) concluded that 'since water sustains all life, effective management of water resources demands a holistic approach, linking social and economic development with protection of natural ecosystems'. For example, upstream ecosystems need to be conserved if their vital role in regulating the hydrological cycle is to be maintained. Well-managed headwater grasslands and forests reduce runoff during wet periods, increase infiltration to the soil and aquifers and reduce soil erosion. Downstream ecosystems provide valuable resources, such as fish nurseries, floodplain forests or pasture, but these must be provided with freshwater and seen as a legitimate water user. At the UNCED Conference itself, it was agreed that 'in developing and using water resources priority has to be given to the satisfaction of basic needs and the safeguarding of ecosystems' (Agenda 21, Chapter 18, 18.8). Thus whilst people need access to water directly to drink, irrigate crops or supply industry, providing water to the environment means using water indirectly for people. The declaration from the Second World Water Forum in The Hague in 2000 highlighted the need to ensure the integrity of ecosystems through sustainable water resources management. South Africa is one of the countries which have taken a lead in implementing this concept. Principle 9 of the new (1998) National Water Act of South Africa states that 'the quantity, quality and reliability of water required to maintain the ecological functions on which humans depend shall be reserved so that the human use of water does not individually or cumulatively compromise the long term sustainability of aquatic and associated ecosystems'. The 1996-2001 Fifth International Hydrology Programme of UNESCO included an Ecohydrology project which includes ecosystem management to improve water quality, particularly in the form of buffer strips to ameliorate the impacts of agricultural pollution. The World Commission on Dams (2000) recommended the release of environmental flows from dams to support downstream ecosystems and their dependent livelihoods.

Figure 2.18 *Percentages of total mean annual river discharge needed to sustain the environment (after Smakhtin et al, 2003)*

depletion of organic pollution). In many regions fish are a key element in the social and economic organisation of human communities and are the first source of proteins – sometimes the only one – especially for the poor. Further issues on the importance of the environment in water resources, considering only present climatic conditions and not any further repercussions of enhanced global warming or climate variability, are discussed in Box 2.3.

One of the objectives of the Millennium Ecosystem Assessment is to assess "the ecosystem (and consequent economic and public health) impacts of plausible future scenarios of change in "driving forces," such as population, consumption, climate, technology and economic growth"[2] . A series of integrated ecosystem assessments are being conducted throughout the world, in an effort to analyse the capacity of an ecosystem to provide goods and services important for human development. In fact, no nation or global institution has ever undertaken a comprehensive assessment of how well ecosystems are doing in meeting human needs.

However, the primary question to be asked really is whether humanity would be able to create and maintain socio-economic conditions under which enough water can be secured to sustain the ecosystems themselves, and this under the conditions of all other drivers of potential water scarcity, including climate.

There are several possible ways of analysing environmental water scarcity.

Recent study by Smakhtin et al (2003) combined a concept of environmental water stress indices (comparing the amount of water needed to sustain a functioning ecosystem with the amount left in a river basin after all other "non-environmental" water requirements have been met), with a water stress index (see also section 3.2, and e.g. Figure 2.5 in this chapter), to evaluate global environmental water requirements (Figure 2.18 and 2.19). The long-term total annual water resources available were calculated as an average water discharge from a river catchment by a WaterGAP 2 global model) with a spatial resolution of 50 by 50 km (Alcamo et al, 2002). Percentages of this total river discharge needed to sustain the environment are shown in Figure 2.18, and they range globally from 20 to 50 % of the mean annual water resources.

Figure 2.19 illustrates the distribution of water stress index by taking into the account explicitly environmental water requirements. Comparing results presented in Figure 2.19 with previous calculations of water stress index without environmental water needs (see Fig 2.5 in section 2.1) reveals that when the ecosystem's water requirements are considered, more river basins show a higher degree of water stress. The circled basins are examples of basins where over-abstraction of water is causing problems to ecosystems and people depending on the ecosystem services.

Balancing environmental water needs with other functions of the water management system is clearly a matter that involves multiple stakeholders and would benefit from a Dialogue-style approach (see Chapter 4). Box 2.4 and Figure 2.20 record some experiences from the Dutch-Belgian River Scheldt Estuary.

[2] http://www.millenniumassessment.org/en/about/concept.htm

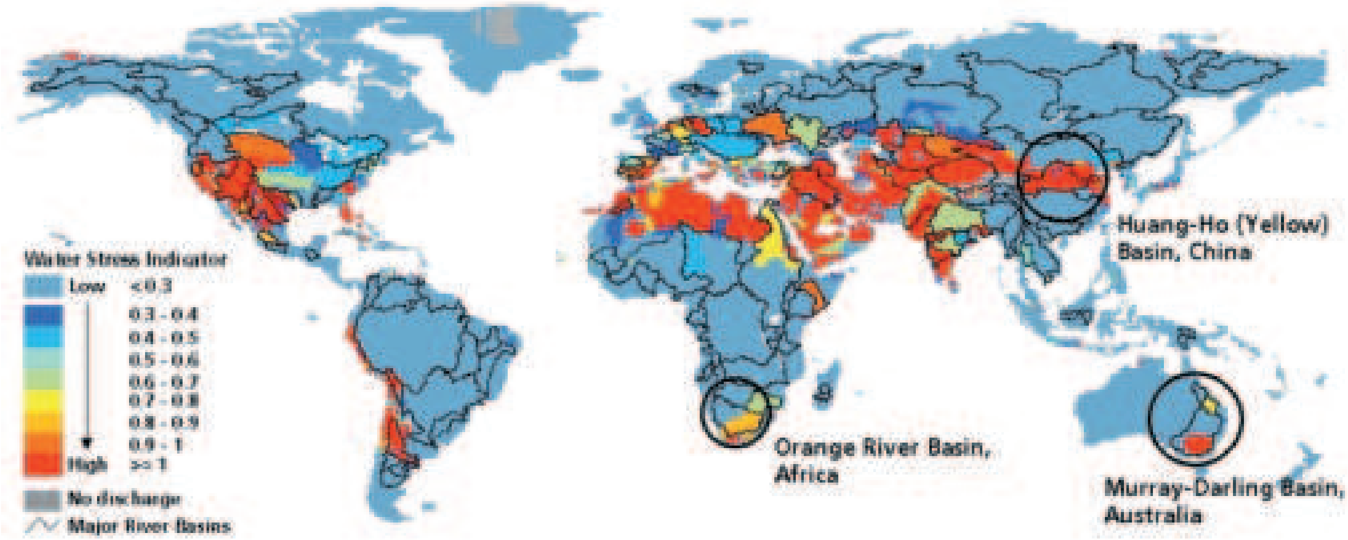


Figure 2.19 *Global distribution of water stress index when environmental water requirements are explicitly taken into the account (after Smakhtin et al, 2003). Compare with Fig. 2.5 in section 2.1., where the water stress index is presented without accounting for environmental needs.*

Box 2.4 The importance of the environment in water resources.

"Safety is the main objective of water management in the Scheldt Estuary". This is the message of the interview HRH the Prince of Orange gave in February 2003 in remembrance of the devastating flood in 1953 that took away almost 2000 lives in the Dutch and Belgian estuary (a death toll unprecedented for the Netherlands).

The 1953 floods spurred the development of major flood protection works, at least partly closing all but one river branches from the sea. For - not withstanding the vital importance of safety - different interests have to be taken into account. Situated on the Flemish Dutch border, the estuary sustains four major ports, as well as rare salt marshes and a growing human population. The inserted figure illustrates the major uses of the estuary. Public awareness on environmental problems, such as chemical and sewage pollution, the loss of rare natural habitats and the transport of hazardous substances has increased. Signifying its ecological importance the estuary comes under the EU habitat directive, requiring spatial compensation for any loss of ecologically significant land.

In recent years every large intervention or engineering work has had to be weighted against these diverse interests, slowing down policy planning more and more. To facilitate policy planning, integrating the diverse needs and demands of stakeholders, the Ministry of Transport, Public Works and Water Management of the Netherlands and its Flemish counterpart decided to develop an integral long-term vision on the estuary in 2030. This vision is intended to guide policy makers in both countries. The vision was built on the three interests that were identified as most crucial to the estuary and its users: navigation (supporting access to the ports), safety (providing adequate protection against flooding) and environment (protecting and restoring the estuarine ecosystem). Bilateral officials worked together over a two-year period to develop the vision from a carefully created common understanding of the present and near future. Stakeholder participation was recognised as crucial in the development and acceptance of the vision. Participation and institutional arrangements were carefully designed to facilitate the input of interest groups and researchers. In addition bilateral decision makers and politicians were invited to give authorisation to the vision.

Both through the participative project approach and the focussed input from joint scientific research, mutual understanding of the estuarine system has increased between the two countries and between the different stakeholders. This is a decisive step in sustainable development of the Scheldt Estuary, balancing safety, environment & navigation. It will facilitate consensus on the mid-term strategies that are currently under preparation in the development plan 2010.

After policy makers have agreed on their objectives, a detailed research program is to be commissioned that will evaluate the effects of engineering works and management strategies. This includes the impacts of climate change. Given anticipated sea level rise and an increased risk of flooding, policy makers and water managers recognise more than ever that dikes cannot be raised over and over again in the Netherlands and instead more space has to be assigned to the river system.

The remembrance of the 1953 flood recalled the devastating power water can have and drew attention to the impacts of climate change as a driving force behind decision making.

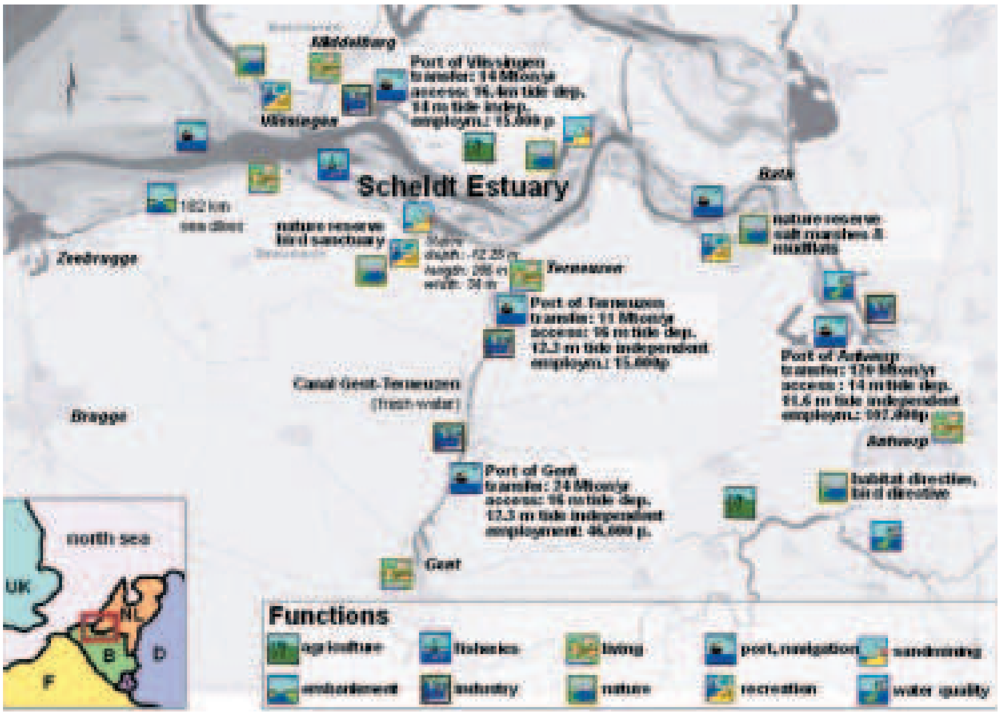


Figure 2.20 *Multiple uses of the Scheldt Estuary.*

Whatever the cause of modification of wet ecosystems, climate or otherwise, the result often has detrimental consequences for a variety of sectors, including livelihoods of humans. For example, a model study in the Yobe Basin of the Chad Basin in Nigeria showed that anthropogenic factors accounted for more than 45% of the observed changes in wet ecosystems. The consequences are listed in Box 2.5. However, not all modifications in wet ecosystems have adverse impacts on livelihoods—humans can often adapt and thrive in new environments. A prime example is the adaptation by local communities to the shrinking of Lake Chad, described in Chapter 4 (see section 4.5)

2.4.1 Impacts on wet ecosystems

Wetlands and lakes are by nature very complex ecosystems both in time and space. It is still not possible to separate climate impacts on wetlands from those created by historical trends and human demands for ground and surface water (Covich et al, 1997). The difficulty in teasing out those impacts on wet ecosystems that are due solely to climate change comes from the plethora of confounding factors or driving forces which influence their state (see Table 2.2).

Medium	Description
Climate (both natural variability and anthropogenic climate changes)	Absolute rise or fall in temperature Change in growing season length Absolute rise or fall in precipitation Increase in variability of temperature and/or rainfall Change in frequency of extreme weather events
Chemical Inputs (> 90 % anthropogenic drivers)	Nutrients (point and non-point sources) Toxic chemicals (heavy metals, petrochemicals, acid rain, antibiotics)
Water (both anthropegenic and climate related drivers)	Fluctuations in Ground and/or Surface Water Absolute change in Ground- and/or Surface Water flows
Biodiversity (changes largely due to anthropogenic activities)	Loss of migrants due to extra-regional losses of habitat or species Invasion of exotics better adapted to new environmental conditions
Land Use Change (changes largely due to anthropogenic activities)	Habitat Fragmentation Decrease in size (area, range Homogenization (loss of diversity of habitats or extent of ecotones) Changing landscape morphometry (Hydro-engineering)
Energy (entirely anthropogenic activities)	Biomass harvest

Table 2.2 *External drivers/forcers of wetland ecosystem dynamics (Sendzimir, 2002)*

Box 2.5 Consequences of Changes in Wetlands in West Africa (West Africa Dialogue Report, 2003)

- Drastic reduction (in northeastern Nigeria by more than 80%, and in the inner Niger Delta by more than 60%) of the surface area of the inundated floodplain used for recession cultivation of rice, cotton, etc, as spawning and growth of fish, to support the thousands of migratory birds;
- Significant reduction of recession rice cultivation by up to 60% in many of the floodplains;
- Collapse or near collapse of the fishing industry in the inner Niger Delta and Chari-Logone Wetland, and reduction of the number fish species by at least five in the Hadejia-Nguru Wetlands of NE Nigeria.
- Severe impacts on the regional rural economies, and subsequently (via migration of battalions of unemployed persons) the urban communities.
- Overexploitation of most of the coastal resources leading to the depletion of the stocks but also to the degradation and sometimes the destruction of some ecosystems e.g. in Côte d'Ivoire and Guinea Bissau some 60 and 70% of the mangroves have been lost respectively;
- Pollution of coastal waters especially in urban centers and conversion of coastal ecosystems for other purposes like for example, mangrove clearing for salt production or development of tourist resorts or urban centers.
- Inefficient and non-sustainable water management approach devoid of demand management, low water supply level and coverage

2.4.2 Direct climate impacts

If rainfall is reduced and temperature is increased, the following direct impacts on wet ecosystems can be anticipated:

- Lower flows in streams and overland surface waters, associated with generally lower import of chemicals to lakes from catchments and possible increase of lake concentrations of sodium and chloride
- Lower levels in water tables and open water bodies (lakes, ponds)
- Lower rates of groundwater recharge
- Higher air temperatures associated with longer growing season, shorter duration and extent of ice cover, expanding aerobic zone in soil substrate, higher temperatures in streams and in lake epilimnion layers, and less habitat for cold water fish species

Box 2.6 provides several examples of decreasing surface areas of lakes due to decreased water flows and increased evaporation, as well as increased surface areas of lakes due to glacier melt.

Box 2.6 Climatic impacts on lakes (Robarts et al, 2003)

Although it is sometimes difficult to discern the impact of climate variability and climate change on lakes from direct human activities, it is interesting to review a number of examples where the combination of decreased water inflows and increased evaporation rates can have major impacts on water levels even in very large lakes. This is especially true for semi-arid regions of the world, such as southern Africa, central Asia and the Prairie and Great Plains of North America. For example, the water level in Devils Lake, North Dakota, dropped almost 12m between about 1865 and 1940, almost drying out the lake completely (Covich et al. 1997). Other lakes and reservoirs in southern Africa may completely dry out, such as occurred with Lake Chilwa in Malawi in 1997. The water level of Lake Qinghai in China decreased by 3 m from 1959 to 1995 due to both the decrease of inflow and an increase of evaporation (Nakao 1997). Lakes in these regions are generally shallow with large surface area to volume ratios. The water level changes strongly affect the riparian areas and the species that depend upon them.

In other lakes, water levels may rise due to climate warming. For example, the water level of Lake Hovsgul in Mongolia, which belongs to the boreal zone, is rising and it might be caused by permafrost and/or glacier melting (Kumagai et al. in press). Significant loss of ice from glaciers has been documented in other parts of the world such as in the Rocky Mountains where the Athabasca Glacier has receded 1.5 km in the twentieth century (Schindler 2001).

2.4.3 Indirect climate impacts

Indirect impacts of climate change on the physical, chemical and biological characteristics of wet ecosystems impact species and organisms living within them.

These indirect effects of climate change can result in

- Disruption of flowering phenology
- Shifts in vegetative season
- Species invasions
- Range extensions or contractions,
- Distances between refuges (e.g. water oases)
- Changes in productivity of the ecosystem
- Shifts in nutrient cycles related to fluctuations in water levels
- Changes or declines in hydrological connectivity that can lead to loss of habitat critical to faunal life stages, i.e. fish (Box 2.7)
- Occurrence and/or shifts in intensity and frequency of structuring processes (fire, flood, pests).

Box 2.7 Climatic impacts on lakes (Robarts et al, 2003)

Climate warming can have direct affects on fisheries. For example, waters of many large unstratified northern lakes that currently support cold-water fisheries may warm to above the optimum temperature for species such as lake trout, thereby lowering the production of desirable species. Even sublethal temperature increases could also impact these fish (DeStasio et al. 1996, Schindler 2001). Increasing thermocline depths can decrease the subthermocline habitats available as summer refuges for cold-water species (DeStasio et al. 1996). Such processes could lead to an increase of warm-water species, which might affect cold-water species more directly than thermal stress.

2.5 Water, Climate and Energy

Hydropower generation is the energy source that is most likely to be impacted by climate change and climate variability as it is sensitive to the amount, timing, and geographical pattern of precipitation as well as temperature. Changes in river flows have a direct impact on the amount of hydropower generated, because hydropower production decreases with lower flows. Not only does less water run through the turbines in power houses, but the lower reservoir levels reduce the water pressure and hence the power produced by a given amount of water. In the Colorado River's lower basin, for example, a 10% decrease in runoff reduces power production by 36% . During low flow periods, political pressures on hydropower interests to provide water for the environment intensify. Climate fluctuations also impact electric load patterns, and changes in the frequency-intensity-duration characteristics of extreme events (e.g., floods, droughts, freezing rain) can affect the performance and safety of associated infrastructure such as dams, powerhouses, and transportation and distribution networks.

Box 2.8 Effects of La Niña on Kenya's hydropower production

As a result of the 1997/8 La Niña drought in Kenya, hydropower generation fell to about 48% of the normal rate (3,497.6 GWh in 1998 against 1,793.8 GWh in 2000). This imposed a very high cost on the country because of the need for power rationing, importation of electricity from Uganda and increased investment in thermal generation, as well as from lost revenue and lost jobs in industries where replacement energy could not be arranged. It is estimated that the Kenyan Power and Lighting Company (KPLC) lost Ksh 1.6 billion and, partly due to that, the company was considering laying-off 1,700 employees out of a total workforce in 1999 of 9,283. The high cost and restricted access to water was catalytic in causing some industrial enterprises in Mombasa to relocate to Nairobi and even neighbouring countries.

Source: Mogaka et al, 2002. Impacts and Costs of Climate Variability and Water Resources Degradation in Kenya. A report to the World Bank, Washington

The Kenya example suggests that there may be socio-economic value in exploiting climate predictability (see section 1.4.2). Seasonal climate and dam inflow forecasts are potentially useful for: (1) optimising water use and power generation; (2) assessment of the hydrologic safety of dams and disaster preparedness; and (3) financial planning and enhancement of profitability. Better inflow forecasts assist estimation of the overall power generation expectancy for a given year. They also help in decisions regarding the reservoir space to be reserved for flood control. Greater forecast confidence means a decrease in contingency reserves. Other benefits would be better use of the resource, and a decrease in the number of possible events that have to be planned for (Bates, 2002). Experimental long-range streamflow forecasts for the Columbia River in the USA have been demonstrated to have economic value to water resources management in the Pacific Northwest, particularly in the context of hydropower planning and marketing. Simulated benefits to spot-market energy revenues in the Columbia basin associated with the use of ENSO-based, long-range streamflow forecasts are in the order of US$150 million per year (Hamlet et al, 2002).

Hydroelectric projects generally are designed for a specific river flow regime, including a margin of safety. Projected climate changes are expected to change flow regimes – perhaps outside these safety margins in some instances. Although it is not yet possible to provide reliable forecasts of shifts in flow regimes for world river systems as a consequences of climate change, what is known suggests more intense rainfall events (which would require more conservative water storage strategies to prevent flood damage), greater probability of drought (less hydroelectric production), and less precipitation falling as snow (less water available during warm months). All three factors point to less (or, at least, less flexible) hydroelectric capacity at existing powerhouses. Reduced flows in rivers and higher temperatures reduce the capabilities of thermal electric generation; high temperatures also reduce transmission capabilities.

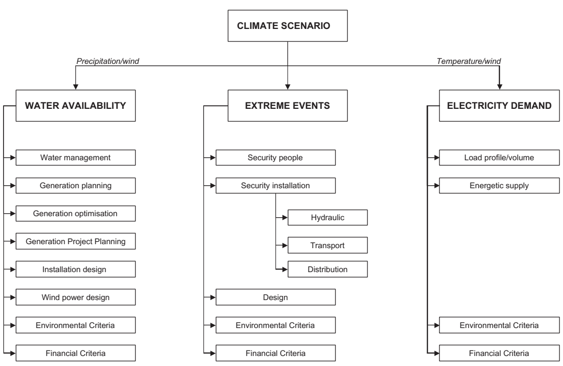
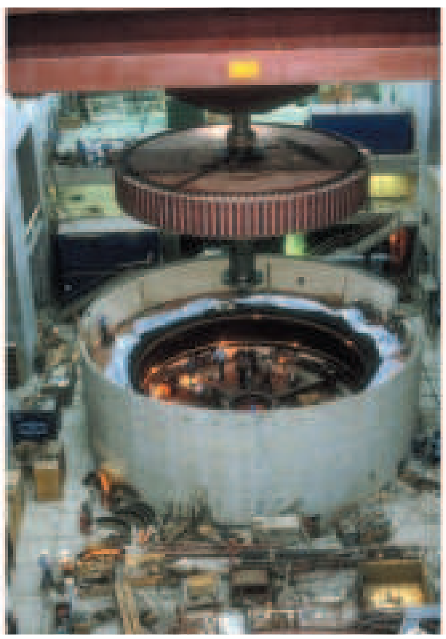


Figure 2.21 *Most important fields of activities in the hydropower sector that might be affected by climate change (Roy and Desrochers, 2002)*

In analysing the impact of climate change on hydroelectric supply, Roy and Desrochers (2002) first identified the most important activities that might be affected by climate change (Figure 2.21). The fields of activities can be arranged in three different groups (first level concerns) according to the anticipated affects related to the modification of:

- the hydrological regime → water availability
- the thermal regime → electricity demand and
- the occurrence of extreme events.

Expected impacts include increased energy demand for space cooling due to higher summer temperatures, and decreased energy for space heating due to higher winter temperatures. The net effect is scenario and location dependent.



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Chapter 3: Assessing vulnerability

3.1 What is vulnerability?

The impacts of climate variability affect everyone, and there are few places in the world that will not be affected by long-term climate change. There are major differences though in the capacity to cope with those impacts, depending on where they occur. The citizens of London, New York or Sydney may feel aggrieved if a prolonged drought means that they have to forego washing their cars or watering their gardens. In the shantytowns of Third World megacities, the impacts of water scarcity are much more serious. Cramped and crowded living conditions magnify the risks of disease epidemics when polluted ponds or ditches become the only available water sources. At the other climatic extreme, low-cost houses on marginal land in flood plains or on mountainsides are the first to go when intense rainfall brings inundation and landslides. For the poor, threats from extreme weather events are compounded by the limited options they have to respond.

There are other compounding factors too. Existing water or food scarcity makes some regions more sensitive to droughts and temperature rise; geographic considerations are important when considering the potential impact of sea level rise; and countries with low levels of human and economic development also have a reduced capacity to cope with the impacts of climate variability and climate change.

Box 3.1 Defining vulnerability

Many different agencies and individuals have contributed to the development of assessment techniques for vulnerability to climate change and, to a lesser degree, climate variability. A good summary of the resulting plethora of terms (impact potential, resilience, sensitivity, responsiveness, adaptability, adaptive capacity and vulnerability) was prepared by Olmos (CCKN, 2001). For this report, we have confined the discussion to three principle parameters, defined by IPCC (2001) as:

Sensitivity: the degree to which a system is affected, either adversely or beneficially, by climate-related stimuli;

Adaptive capacity: the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences; and

Vulnerability: the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. It is, amongst others, a function of the character, magnitude and rate of climate variation to which a system is exposed, its sensitivity and its adaptive capacity.

It is clear that assessing the "vulnerability" of a particular community, river basin or geographic region to climate variability and climate change involves more than long-range weather and climate prediction. It means combining updated hydrological data with appropriate sectoral, geographic and developmental indicators. It is an exercise that ideally needs to be based on local analysis of local data and a local evaluation of adaptive capacity. A lot of work is going on in different agencies to develop methodologies for this "bottom-up approach" to vulnerability assessment. Chapter 5 refers to the research being undertaken by the World Bank, the Red Cross and the UNEP/WMO/IPCC initiative Assessment of Impacts and Adaptations to Climate Change (AIACC). There are also promising early results emerging from studies at the Centre for Ecology and Hydrology (CEH) into a "Climate Vulnerability Index" (CVI). Based on previous developments of the Water Poverty Index (Sullivan et al, 2002), the CVI allows a combination of variables representing resources, access, capacity, use, environment and geospatial conditions to be used, according to the geographic types being compared (e.g. small islands, mountainous regions, coastal zones, megacities, arid and semi-arid areas). Figure 3.1 shows some preliminary results of applying the CVI approach in a top-down way to compare climate vulnerabilities of different regions at present and how it might be affected over 30 years if development follows UNEP's "Policy First" scenario (see Section 3.2). In Sections 3.3 and 3.6, we look further at the CVI methodology and its application.

While the CVI approach is promising, so far there is no universally applicable way of comparing local vulnerability from one location to another. One recommendation of this report is for coordination and consolidation of research efforts to develop and test vulnerability indicators and assessment methods that can be used by local groups. The DWC-sponsored multi-stakeholder dialogues described in Chapter 5 are seen as effective organizations to undertake local vulnerability assessments.

In the meantime, the development community is hungry for comparative data on critical regions or "hot spots" in respect to climate change. Governments, donors and NGOs want an overall indication of where people are most at risk. This demand is being partly met by combining the various IPCC climate change scenarios with proxy indicators for the "adaptive capacity" of different countries (working definitions of the terms "sensitivity", "adaptive capacity" and "vulnerability" are given in Box 3.1). The data can be combined in many different ways, though all suffer from the uncertainties and the spatial scale of the climate change scenarios and the necessary averaging of indicators over whole countries. Accepting these limitations, we are showing here four different cases as examples of techniques for determining vulnerability to climate change and/or variability. It is

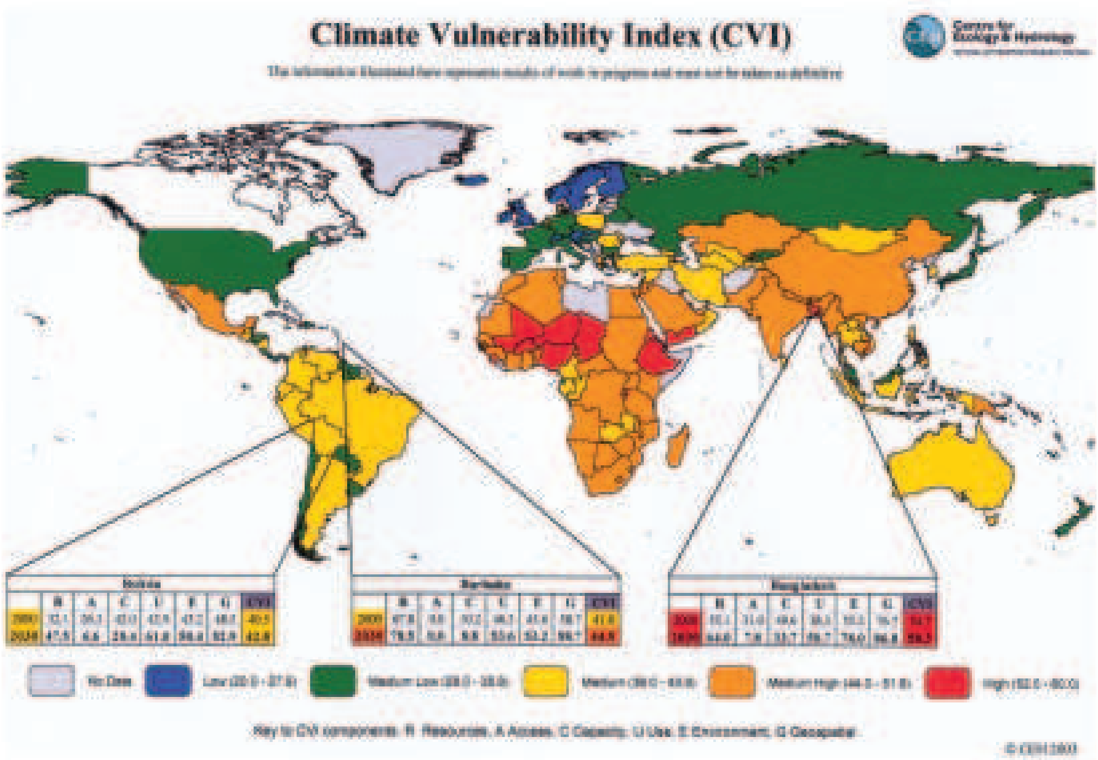


Figure 3.1 *Some preliminary results of applying the Climate Vulnerability Index (CVI) approach to compare vulnerabilities of different regions at present and how it might be affected over 30 years if development follows UNEP's "Policy First" scenario (Sullivan et al, 2003)*

by no means a complete compilation, but it does serve to illustrate different types of results vulnerability assessment methods can provide. The cases are:

1. Global Vulnerability and Critical Regions to Climate Change – Water Stress
2. Sectoral Vulnerability to Climate Change – Food Security
3. Geographic Vulnerability – Small Islands, Low Coastal Areas and Megacities
4. Developmental Vulnerability – Millennium Development Goals

3.2 The water stress index applied to climate

The concept of water stress is commonly used to obtain a global overview of the state of water resources, by comparing availability with demand. 'Water stress' is an indication of the amount of pressure put on water resources and aquatic ecosystems by the users. Generally speaking, the more often water is withdrawn, used, and discharged back to the river, the more it is degraded or depleted, and the higher the water stress. The higher the water stress, the stronger is the competition between users, and the greater the limitation on further use of these water resources downstream.

In developing countries, a level of severe water stress indicates an intensive level of water use that is likely to cause rapid degradation of water quality for downstream users and absolute shortages during droughts. Also, in both developing and industrialised countries, a level of severe water stress indicates strong competition for water resources during dry years between municipalities, industry, and agriculture. In most studies, severe water stress appears mainly in arid areas of the world, but it also occurs in the more humid drainage basins of the world.

As part of the 1997 Water Futures: "Comprehensive Assessment of Freshwater Water Resources of the World", Raskin et al. (1997) define three components

Box 3.2: Water stress as "withdrawal to availability ratio"

A typical measure of water stress is the annual 'withdrawals to availability ratio' (WTA). According to this indicator, water stress increases when either water withdrawals grow (related to changes in population and economic growth), and/or water availability decreases (due to pollution or climate change). This indicator has the advantage of being transparent and computable for all basins, although it implies a strong simplification of the processes of water scarcity. Results by Alcamo et al (2002) presented in Chapter 2 (Section 2.1, Figs. 2.5 and 2.6) assumed that river basins with a WTA ratio greater than 0.4 are under severe water stress. This value was selected by the World Water Commission (Cosgrove and Rijsberman, 2000) and a Consortium of UN organizations (Raskin et al., 1997), based on expert judgement, as an approximate threshold of 'severe' water stress and an indication of heavy competition between water users. Water stress is classified as 'low' (WTA lower than 0.2), 'medium' (WTA between 0.2 and 0.4), and 'severe' (WTA larger than 0.4).

which contribute to their water stress indicators: Reliability (R), Use to Resource Ratio (U/Rr), and Economic Coping Capacity (ECC). Two indices are proposed:

Water Stress 1 (WS1): The average of the three individual components.

Water Stress 2 (WS2): The maximum value of any of the three components.

The introduction of Economic Coping Capacity is significant, emphasising that the stress is greater when the capacity to cope is less. In the case of water stress composite 1 (WS1), coping capacity compensates for greater resource stress.

Country	1995				2025				WS2 Change 1995-2025
	R	U/Rr	ECC	WS2	R	U/Rr	ECC	WS2	
Algeria	2	3	3	3	2	4	2	4	increase
Denmark	2	1	1	2	3	2	1	3	increase
Morocco	3	3	3	3	3	4	3	4	increase
Netherlands	2	1	1	2	3	2	1	3	increase
South Africa	2	3	2	3	2	4	2	4	increase
USA	2	2	1	2	2	3	1	3	increase
Brazil	2	1	2	2	2	1	2	2	no change
Bulgaria	3	1	3	3	3	1	3	3	no change
Canada	1	1	1	1	1	1	1	1	no change
Chad	3	1	4	4	3	1	4	4	no change
Mozambique	3	1	4	4	3	1	4	4	no change
Fiji Islands	2	1	3	4	2	1	2	2	decrease
Papua New Guinea	2	1	3	3	2	1	2	2	decrease
Ukraine	2	2	3	3	2	2	2	2	decrease
Russia	2	1	3	3	2	1	2	2	decrease

Table 3.1. *A comparison of water stress for 1995 and 2025 for selected countries according to "Comprehensive Assessment of Freshwater Water Resources of the World", (Raskin et al., 1997). Calculations for 2025 are based on the GFDL climate scenario, and mean Conventional Development Scenario.*

Results of Raskin's et al. assessments suggest that in 2025, water stress will in most cases either be reduced or stay the same due to population and economic changes. Calculations based on projections of climate change and development to the year 2025, reveal that of the 160 countries analysed, 116 remain the same, 34 exhibit a decrease, and only 10 countries exhibit an increase in water stress (WS2) in 2025. A sample of these countries is shown in Table 3.1.

When the composite value of water stress is determined as an average of the three components (WS1), there are only seven countries that exhibit an increase in water stress; the rest do not change in status from 1995.

Any water stress calculations need to be based on assumptions about future driving forces which include population growth, economic growth, technological change and other socio-economic data. To allow for comparisons between different modelling studies or between regions, these drivers would normally be derived from more general "lworld evolution" scenarios. The four "story lines" (A1, A2, B1, B2) developed by IPCC –SRES (see section 1.5.3) are typical examples of evolutionary paths used in many climate vulnerability studies, including the study by Alcamo et al (2002) as reported in Chapter 2 (section 2.1, Figs. 2.5 and 2.6).

Other developmental scenarios are suggested in the GEO-3 report (UNEP, 2000 and 2002) (see Box 3.3). As shown in Section 3.3, Sullivan et al (2002) propose to use UNEP scenarios in developing and evaluating the Climate Vulnerability Index.

3.3 Climate Vulnerability Index

To make it possible to focus on the impacts of climate change and variability, Sullivan et al (2003) extended the Water Poverty Index concept (Sullivan, 2002) to come up with a Climate Vulnerability Index (CVI). The CVI score is on a scale of 0 to 100 (100 being the highest vulnerability). It is generated from six major components, each of which can include several variables[1]. An example of its application at the global level was given at the start of this chapter and a more localised application is described in section 3.6.

1. See also section 3.6, where CVI is applied to selected small islands by way of a scoping study. CVI component values are derived from the equivalent WPI components, with a Geospatial component added. For the small island case study, this is a combination of an isolation index (based on distance from the mainland and land area) and the extent of land at risk from sea level rise (approximately estimated from available topographic maps). The changes in the components were based on the UNEP "Policy First" scenario, and estimated as follows:

- Resources – change in runoff from IPCC (2001b, page 202) based on model results generated from the HadCM3 global climate model, combined with changed populations using annual growth rates derived from WRI (2000). A small arbitrary change in variability is also assumed.
- Access – based on change in access to safe water assuming the UN Millennium target for 2015 is met, and then that the same target is applied again and met again. The target is to half the proportion of people without access; thus by 2030, the proportion of people without access would be 25% of the value in 2000.
- Capacity – based on the combination of change in under-5 mortality rates and GDP, with equal weight given to each. For under-5 mortality rates the Millennium target is used in the same way as for Access. The target is to reduce the rates by two-thirds; thus by 2030, the rates would be 11% of the 2000 value. It is assumed that GDPs stay the same in comparative terms between the countries.
- Use – is changed only by the ratio of change in population.
- Environment – the natural capital index values from GEO-3 (UNEP, 2002) for the region or sub-region are used.
- Geospatial – an additional component of the CVI, not part of the Water Poverty Index. See Box 3.6 for the Geospatial elements associated with Small Islands.

Box 3.3 UNEP development scenarios

● **Markets First**

Most of the world adopts the values and expectations prevailing in today's industrialized countries. The wealth of nations and the optimal play of market forces dominate social and political agendas. Trust is placed in further globalization and liberalization to enhance corporate wealth, create new enterprises and livelihoods, and so help people and communities to afford to insure against – or pay to fix – social and environmental problems. Ethical investors, together with citizen and consumer groups, try to exercise growing corrective influence but are undermined by economic imperatives. The powers of state officials, planners and lawmakers to regulate society, economy and the environment continue to be overwhelmed by expanding demands.

● **Policy First**

Decisive initiatives are taken by governments in an attempt to reach specific social and environmental goals. A coordinated pro-environment and anti-poverty drive balances the momentum for economic development at any cost. Environmental and social costs and gains are factored into policy measures, regulatory frameworks and planning processes. All these are reinforced by fiscal levers or incentives such as carbon taxes and tax breaks. International 'soft law' treaties and binding instruments affecting environment and development are integrated into unified blueprints and their status in law is upgraded, though fresh provision is made for open consultation processes to allow for regional and local variants.

● **Security First**

This scenario assumes a world of striking disparities where inequality and conflict prevail. Socio-economic and environmental stresses give rise to waves of protest and counteraction. As such troubles become increasingly prevalent, the more powerful and wealthy groups focus on self-protection, creating enclaves akin to the present day 'gated communities'. Such islands of advantage provide a degree of enhanced security and economic benefits for dependent communities in their immediate surroundings but they exclude the disadvantaged mass of outsiders. Welfare and regulatory services fall into disuse but market forces continue to operate outside the walls.

● **Sustainability First**

A new environment and development paradigm emerges in response to the challenge of sustainability, supported by new, more equitable values and institutions. A more visionary state of affairs prevails, where radical shifts in the way people interact with one another and with the world around them stimulate and support sustainable policy measures and accountable corporate behaviour. There is much fuller collaboration between governments, citizens and other stakeholder groups in decision-making on issues of close common concern. A consensus is reached on what needs to be done to satisfy basic needs and realize personal goals without beggaring others or spoiling the outlook for posterity.

CVI extends the Water Poverty Index (WPI) by adding a new component of geographical vulnerability, referred to as the geospatial component. This brings in extra variables related to specific geographical situations. Geographic vulnerability to climatic impacts can be characterised in many different ways. It can refer to the likelihood of being subject to floods or droughts, land slips or desertification. It may be to do with topography, or isolation, or many other factors. In any particular situation, potential geographical vulnerability has to be identified on the basis of informed judgement and expert opinion.

In calculating the CVI, each of the major components used to characterise WPI (Resource, Access, Capacity, Use and Environment) needs to be included, but the sub-components or variables are selected on the basis of their particular relevance to the assessment of vulnerability to climate variability. As an example, some sub-components that may be appropriate for the CVI are listed in Table 3.2. The actual choice of the sub-components for a particular application also depends on the availability of data and the scale of the study; different variables are available and relevant at different spatial scales.

CVI component	Sub-components / Variables
Resource (R)	● assessment of surface water and groundwater availability ● evaluation of the reliability of resources ● assessment of water quality ● dependence on imported or desalinated water ● water storage capacity
Access (A)	● access to clean water ● access to sanitation ● access to irrigation coverage adjusted by climate characteristics
Capacity (C)	● expenditure on consumer durables, or income ● the under-five mortality rate ● existence of disaster warning systems ● educational level of the population ● percentage of people living in informal housing ● GDP as a proportion of GNP ● strength of municipal institutions ● investment in the water sector as a percentage of fixed capital investment ● access to a place of safety in the event of flooding or other disasters
Use (U)	● domestic water consumption rate related to national or other standards ● agricultural water use related to the contribution of agricultural production to GDP ● industrial water use related to the contribution of industrial production to GDP
Environment (E)	● livestock density ● human population density ● loss of habitats ● flood frequency
Geospatial (G)	● extent of land at risk from sea level rise and/or tidal waves ● extent of land at risk from land slips ● degree of isolation from other water resources and/or food sources ● deforestation, desertification and/or soil erosion rates ● degree of land conversion from natural vegetation ● extent of risk from melting of glaciers ● risk of glacial lake outbursts

***Table 3.2** Potential variables for inclusion as sub-components of the Climate Vulnerability Index (Sullivan et al, 2003)*

In its simplest form, the CVI would be the average of the six component indices. In most cases though, the components need to be weighted to reflect the relative risk of each one being impacted by climate variability or climate change. That is done by multiplying each component by a different risk factor then dividing them by the sum of the factors.

The resulting CVI score for the present situation gives a measure of vulnerability to climate variability now, and allows comparisons between locations. By using scenarios of future conditions, the change in the scores from the present values provides comparative assessment of the vulnerability to climate change (see Figure 3.1).

3.4 Critical regions of water stress vulnerability

A modelling study by Alcamo and Heinrichs (2002) determined "critical regions" based on four different sets of criteria, and four distinctive socio-economic and climate scenarios. It is best viewed as a type of sensitivity analysis for identifying particularly sensitive regions, and not as a substitute for detailed assessment of global change impacts in a particular region.

The analysis compares the change in water withdrawals caused by changes in population, economic growth, and technological change, with the change in water availability (the natural discharge in each watershed) caused by long-term, average changes in precipitation and temperature due to climate change (only annual average changes). Water stress is rated as low, medium or high according to the "annual withdrawals-to-availability ratio" (see Box 3.2). Critical regions are identified as those that experience an increase in water stress on the watershed-level over the modelled period. The results have been categorised according to four sets of criteria for "critical regions" (note these are not mutually exclusive criteria sets, just alternative ways of presenting the results)

1. Watersheds already under "severe water stress" and experiencing any increase in stress, regardless of the rate of this future increase;
2. Watersheds already under "severe water stress", and where the stress will increase at least one percent per year. The assumption here is that society and ecosystems can adapt to a rate of increase of water stress of up to one percent per year without major disruptions
3. Watersheds already experiencing "medium or severe water stress", and where additional water stress will be at least one percent per year.
4. Watersheds already experiencing "medium water stress", and where the water stress will increase at least one percent per year. In addition, these watersheds must be located in regions/countries with a "higher susceptibility category".

The susceptibility criterion in 4 is an attempt to account for the adaptive capacity of the local population and ecosystems. While susceptibility depends on a complex web of technical, social, economic, cultural, and other factors that are difficult to represent globally, the Human-Development Index[2] (UNDP, 1997) is used in this study as a proxy variable. The 'high susceptibility' category is defined as those countries having a HDI in 1995 less than 0.80.

As might be expected, the estimate of critical regions is very scenario-dependent, showing smaller areas under scenarios having smaller increases in water stress. Some regions though always appear as critical regardless of the scenario. These include small parts of central Mexico, the Middle East, the Ganges-Indus region, the Chad region and parts of the Algerian coast.

Table 3.3 shows the percentage of major regions that fall into the critical category according to the different sets of criteria. Here the A2 IPCC scenario (see section 1.5.3) for the 2020s and the ECHAM (Max Planck Institute, Hamburg, Germany) climate model data set is used. As well as showing the major critical regions, the total percentage of critical regions worldwide has been calculated. The highest values are according to criteria set 3. Europe in particular shows very high values for these criteria, which take no account of the susceptibility criterion. Including the HDI-based susceptibility criterion (criteria set 4) virtually eliminates the "critical regions" from the industrialised part of the world, while it has a little or no effect on Africa and Asia.

	CRITERIA SET			
Major World Regions	*1*	*2*	*3*	*4*
Africa	*7.6*	*4.3*	*10.6*	*10.6*
Asia	*19.8*	*9.7*	*24.2*	*23.8*
Australia & Oceania	*4.1*	*0.2*	*4.2*	*0.0*
FSU	*3.3*	*0.2*	*9.6*	*6.1*
Latin America	*6.9*	*4.0*	*8.4*	*4.4*
North America	*6.4*	*1.9*	*18.1*	*0.0*
Europe	*18.3*	*11.8*	*41.6*	*0.5*

Table 3.3 *Percentage of major regions that fall into the critical category according to different sets of criteria under the A2 scenario for the 2020s based on the ECHAM climate data set.*

Figure 3.2 shows where the critical regions are according to criteria set 4 and for the same set of climate scenarios as the results in Table 3.3. Comparison with Figure 2.6 (Chapter 2) shows again how consideration of coping capacity influences both the global extent and the distribution of critical regions.

[2] The aim of the HDI is to give a broader indication of the state of human well-being than the traditional measure of gross national product (GNP). GNP is nevertheless included as one of HDI's three components, the other two being the rates of literacy and infant mortality.

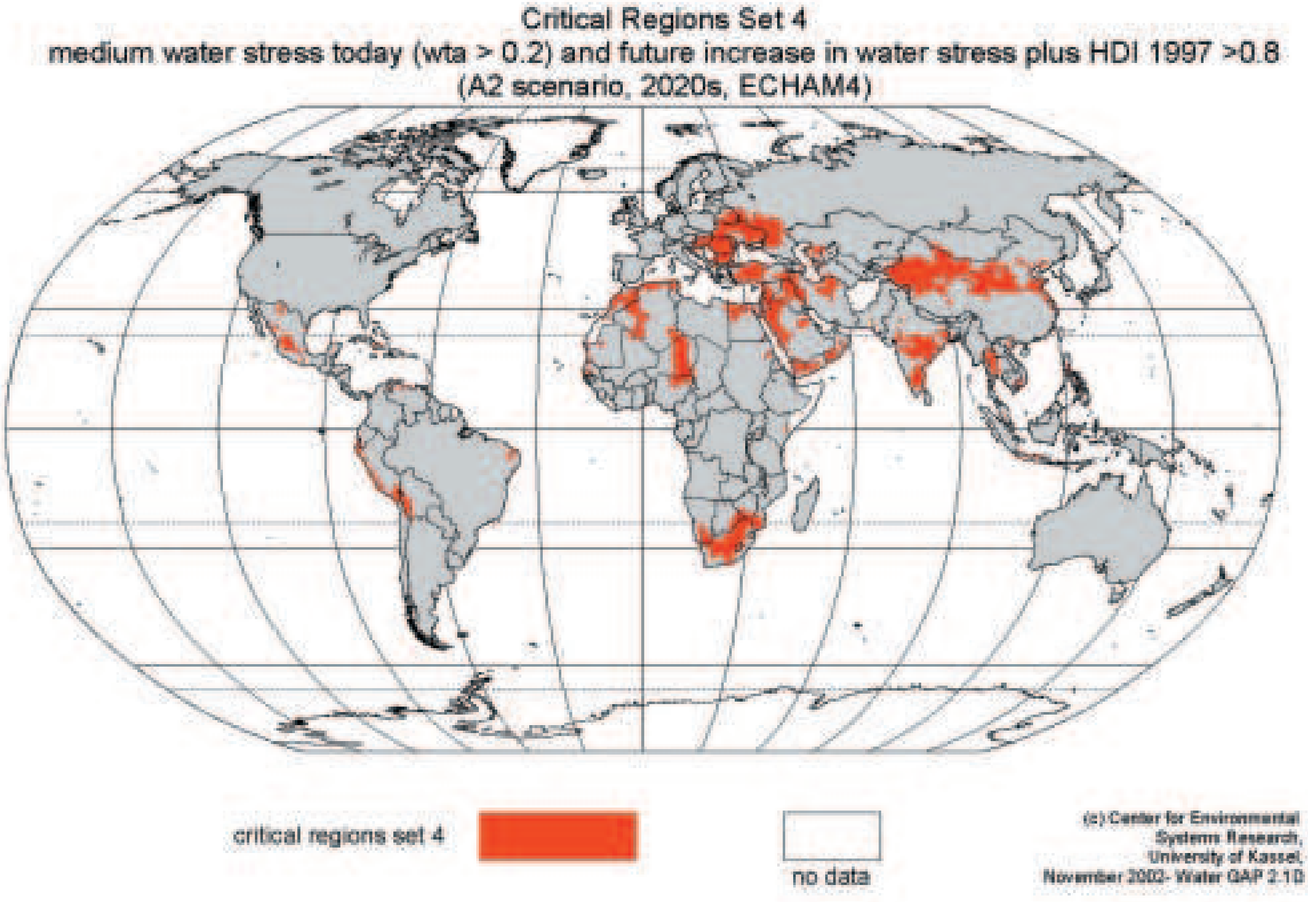


Figure 3.2 *Regions of critical water stress (Alcamo and Heinrich, 2002)*

3.5 Sectoral vulnerability: food security

Agriculture is the world's biggest water consumer and climate variability is farmers' greatest challenge today. Natural variability of rainfall, temperature and other weather conditions is the main factor influencing variability in agricultural production and food insecurity (FAO, 2001)[3] .

Climate extremes - violent and unusual events such as floods and storms - though by nature more apparently dramatic, have less overall effect on agricultural production than chronic climate deficiencies such as droughts. As with other issues, the uncertainties involved in modelling future climate variability on the right spatial and temporal scales make it difficult to simulate the vulnerability of food production on a country-by-country basis.

3.5.1 Current food-insecure countries

The FAO has estimated the total number of undernourished people in 99 developing countries at 780 million (FAO, 2001). Fifteen of these countries, mainly in the Middle East, North Africa, and South America, have relatively high levels of gross domestic product (GDP) per capita – more than US$3,000. These countries, accounting for about 1% of the total undernourished, are not considered to be vulnerable on a national scale, as their adaptive capacity is high. The total population of the remaining 84 food-insecure countries at present amounts to some 4.2 billion, equivalent to 74% of the current world population, of which some 18% are undernourished (Fischer et al., 2002). By the 2080s, the UN projects the total population of these countries to increase to 6.8 billion equivalent to 80% of the world population.

More than half of the undernourished people (61%) are in Asia, while sub-Saharan Africa accounts for almost a quarter (24%). In terms of the proportion of the regional population deemed to be undernourished, the biggest percentage is in sub-Saharan Africa, where 34% were undernourished in 1997-99. Asia and the Pacific comes next with 16% undernourished. It is important to note that significant progress has been made over the last two decades: the incidence of undernourishment in developing countries has come down from 29% in 1979-81 to 17% in 1997-99 (FAO, 2002).

Based on modelling of climate-change scenarios by Fischer et al. (2002), the full group of food-insecure countries, show a net loss of up to 2% in rain-fed cereal production in four of the 12 scenarios[4]. Individual country results give more reason for concern

[3] http://www.fao.org/NEWS/1997/971201-e.htm

[4] For HadCM3 and CSIRO (Australian) climate models

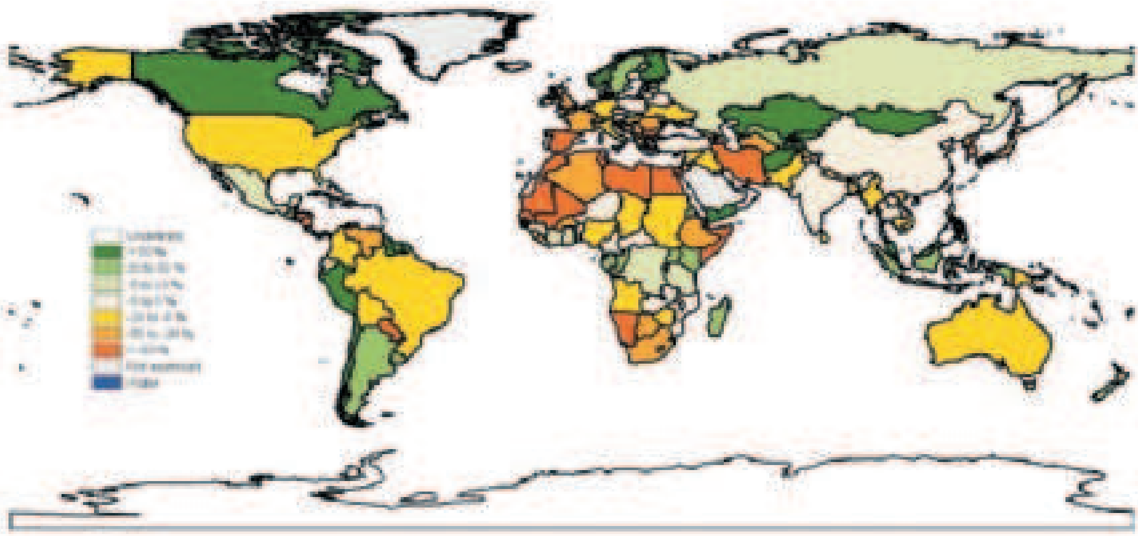


Figure 3.3 *Country-level climate-change impacts on rain-fed cereal-production potential on currently cultivated land (HadCM3- A1FI, 2080s) (Fischer et al, 2002).*

in that up to 40 countries, with a total population in the range of 1–3 billion may lose on average 10–20 % of their cereal production potential in the 2080s due to climate change.

3.5.2 Food-insecure countries in Sub-Saharan Africa

Fischer et al. (2002) show that Sudan, Nigeria, Senegal, Mali, Burkina Faso, Somalia, Ethiopia, Zimbabwe, Chad, Sierra Leone, Angola, Mozambique, and Niger lose cereal production potential in the 2080s[5] for three climate models and across all the emission scenarios. These countries currently have 87 million undernourished, equivalent to 45% of the total undernourished in sub-Saharan Africa. In contrast, Zaire, Tanzania, Kenya, Uganda, Madagascar, Côte d'Ivoire, Benin, Togo, Ghana, and Guinea all gain cereal production potential in the 2080s. These eight gaining countries currently have 73 million undernourished, equivalent to 38% of the undernourished population in sub-Saharan Africa.

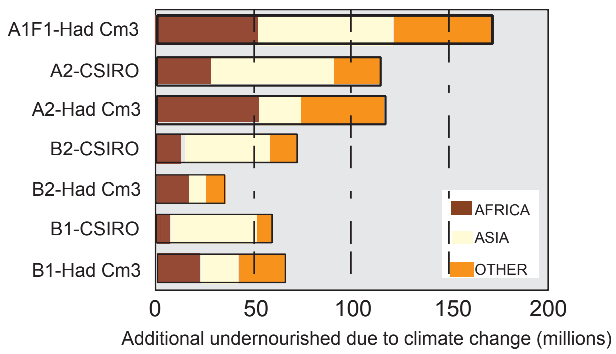


Figure 3.4 *Additional number of undernourished due to climate change, by region, for socio economic conditions of the SRES A2 scenario in the 2080s (Fischer et al, 2002).*

[5] With the exception of the results for the NCAR-PCM model

The balance of gaining and losing countries demonstrates two important factors. First, the net balance of changes in cereal-production potential for sub-Saharan Africa will very likely be negative, with net losses of up to 12% of the region's current production potential. Second, there will be large variations from country to country, with as many as 40% of sub-Saharan countries losing a substantial part of their agricultural production.

3.6 Geographic vulnerability: small islands, low-lying coastal areas and megacities

3.6.1 Small Islands

The global top-down approaches for assessing vulnerability to climate change do not have the resolution to capture the dynamics occurring at smaller scales. It is quite apparent, however, that small island nations and low-lying coastal areas face particular challenges in terms of climate change. The 2001 IPCC Report offers a daunting assessment of the vulnerability and adaptive capacity of Small Island Developing States (SIDS) to climate change and climate variability. The report notes that, because the adaptive capacity of human systems in SIDS is generally low and vulnerability high, they are likely to be among the countries most seriously impacted by climate change. IPCC cautions that islands with very limited water supplies are highly vulnerable to the impacts of climate change on the water balance.

In discussing the special circumstances of SIDS, IPCC (2001) points out that, although they are not a homogeneous group, they share many common features that increase their vulnerability to the projected impacts of climate change. The common characteristics include:

– their small physical size and the fact that they are surrounded by large expanses of ocean;

– limited natural resources, many of which are already stressed;
– proneness to natural disasters and extreme events;
– relatively thin fresh water lenses that are highly sensitive to sea-level changes;
– in some cases, relative isolation and great distance to major markets;
– extreme openness of small economies and high sensitivity to external market shocks;
– large populations with high growth rates and densities;
– poorly developed infrastructure;
– limited funds, human resources and skills.

A wide range of hazards have the potential to impact on water in SIDS, including droughts, floods, tropical cyclones and sea level rise. Agricultural drought is a particular problem for the Pacific atoll nations and the leeward side of larger islands. The most vulnerable communities are impoverished peoples occupying marginal rural and urban environments (ESCAP, 2000).

Floods are a significant hazard in those Pacific Island countries with mountainous terrain. Examples of recent flooding examples in the Pacific Islands are given in Box 3.4. The hazard is greatest when these islands are in the zone affected by cyclones and their associated extreme precipitation intensities. Floods can result in loss of life and extensive property damage, especially when river floodplains have been settled and/or cultivated. In cyclone conditions, the effects of floods are often exacerbated by high-intensity rain-induced landslides and resulting debris that can obstruct river channels and create potentially hazardous temporary dams. The hazards that floods present to any structure also threaten water supply infrastructure (e.g. damage to intake works, treatment plants or distribution networks) and river flow monitoring stations. Floods can also threaten water supplies in a less direct way by compromising water quality.

Tropical cyclones are a serious hazard in most Pacific Island countries but are more frequent in the western and central Pacific than in the eastern Pacific. The very high wind speeds of tropical cyclones are often accompanied by extremely intense rainfall and storm surge that is likely to be amplified by the associated low atmospheric pressures. This combination can result in destruction of buildings and gardens, damage to tree crops, flooding, coastal inundation, and erosion, pollution of water supplies and destruction of coral reefs.

Global warming is projected to bring more frequent and more intense storms to higher latitudes of the Pacific Islands region. In the near future, increased

Box 3.4 Examples of major flood events and impacts in the Pacific Islands

This range of hazards has been demonstrated in recent flooding in various Pacific Island countries:

in 1986 Cyclone Namu caused widespread property damage in the Solomon Islands and floods which resulted in the destruction of several highway bridges and the loss of river flow monitoring sites.

in 1987 Cyclone Uma hit Vanuatu where it was reported as being the worst cyclone in living memory in South Efate. The resulting widespread damage included the destruction of hydrological stations.

in 1991 Cyclone Val devastated the islands of American Samoa. Water supplies were adversely affected when flooding caused by the accumulation of debris resulted in the inundation of wellheads.

in 2001 flash floods in Samoa (Upolu) caused by extreme rainfall intensities associated with an unpredictable micro-weather system resulted in widespread damage including the contamination of potable water supplies and destruction of river flow monitoring sites.

Typhoon Chata'an in 2002 completely destroyed or badly damaged all 11 flow monitoring sites in the Guam streamgauge network.

(Falkland et al., 2002)

Box 3.5 Cyclones in the Pacific

Tropical cyclones are damaging for low-lying islands particularly where changes in land use practices have tended to reduce the natural resilience of subsistence life styles and increased the risk of soil erosion:

In 1980 Cyclone Ofa caused extensive damage to the atoll islands of Tokelau.

Public buildings and houses were extensively damaged, gardens and tree crops were destroyed, and inundation of sea-water washed away or contaminated the remaining topsoil.

Cyclone Ofa also caused devastation in both Samoa and American Samoa where the widespread property damage was exacerbated by flooding problems resulting from the accumulation of debris in streambeds.

In 1983 a sequence of five cyclones which struck French Polynesia had a devastating effect on many atoll villagers with storm surge conditions submerging or totally removing some villages. Groundwater resources were contaminated by seawater inundation, boats and fishing equipment were destroyed and vegetation and tree crops were extensively damaged.

In Pohnpei (Federated States of Micronesia) large-scale forest clearing for commercial kava plantations resulted in massive landslides after a severe cyclone in 1997. The landslides caused loss of life, ruined plantations, and damaged coastal coral reef communities.

(Falkland et al., 2002)

storminess is projected for a region extending north and east of Hawaii to the area north of Micronesia and westward to the North Mariana Islands. It will become even stormier later in the century and encompass Hawaii, Micronesia and the Marshall Islands.

The potentially catastrophic effect of sea level rise on small islands has often\ been pointed out. Many islands have most of their land less than 3 to 4m above present mean sea level, and even on islands with higher elevations most of the settlements, economic activity and infrastructure are at or near the coast (Sullivan et al., 2002). Thus, sea level rise is expected to have a disproportionately large impact on economies and societies of many small islands (Lal et al., 2002). The results of a sea level rise assessment in the Caribbean are given in Box 3.6.

Box 3.6 Sea Level Rise Assessment for three islands in the Caribbean (CEHI, 2002)

IPCC's predictions that many coastal areas are likely to experience increased levels of flooding, accelerated erosion, loss of wetlands and mangroves and saltwater intrusions into freshwater sources, are supported by the results of the coastal vulnerability assessments that were conducted at select sites in Barbados, Guyana and Grenada[6].

For Guyana, the assessment noted that agriculture, human settlements, infrastructure, fisheries and water resources were likely to be significantly affected by sea level rise (SLR), due to erosion, inundation and salinisation. Under certain SLR scenarios, there could be inundation of up to 150m inland in the capital (Georgetown) and Onverwagt. The intrusion of brackish water into the upper reaches of Demerara, Mahaica and Essequibo Rivers has also been predicted, posing serious consequences for agriculture, with the prime agricultural lands being seriously affected. In the Georgetown area, it may be necessary to retreat up to 5km inland to avoid the consequences of SLR.

The assessment for Grenada found that the most significant impacts of SLR would be on human settlements and coastal infrastructure, tourism and water resources. According to one scenario (1m SLR by 2100) the beaches at all sites will disappear and there will be significant inundation of coastal infrastructure.

A combination of the same scenario with the added impact of a storm surge from a Category 2 Hurricane is likely to flood homes, businesses and other social and economic infrastructure in all the sites studied.

For Barbados, tourism, human settlements and water supply were shown to be extremely susceptible to SLR. With respect to biophysical impact, erosion and inundation were ranked as a more pressing concern than salinisation. Direct damage from storms plus beach erosion could devastate tourism. The results of the assessment indicated that virtually the entire south and south-west coasts of the island will be exposed to elevated water levels during a 1:100 year storm and extensive flooding of these areas can be expected.

Application of the Climate Vulnerability Index (CVI) to Small Islands

Illustration of the CVI approach for small islands (see Box 3.7) draws on Water Poverty Index (WPI) data at the national level in Lawrence et al. (2003).

Preliminary component and CVI values for the present situation (2000) and for the year 2030 for four small island countries are shown in Table 3.4, following the UNEP Policy First scenario (see Box 3.3). A number of approximations and simplifying assumptions have been made to generate these data, so the values must be treated as an illustration only. The Policy First scenario is used because the conditions of this scenario allow us to assume that the Millennium Goals on access to safe water and on health (massive reductions in under-5 mortality) are met. In addition, this means that the Access and Capacity components of the CVI index (see Table 3.2) improve enormously in the poorer countries (Comoros and Trinidad), while in the others they do not change much, as they are already good.

Overall, the results show that the poorest country, Comoros, is the most vulnerable under present conditions. In the future, the results indicate that it will remain the most vulnerable, but the increase in vulnerability for the other countries will be much larger. This is especially so for Bahrain, where there is a relatively large amount of land at risk from sea level rise, resources decline due to population growth and the environmental situation worsens. For other scenarios, in which Millennium Goals would not be met, vulnerabilities would show a larger increase in all cases.

Unfortunately, no data were available for the most vulnerable islands – the smallest and most low-lying ones. It is clear that such places would have high CVI values already, and that they would tend to increase, primarily due to increasing populations often concentrated into the risk areas and the projected increase in variability in climate, rather than because of major shifts in total rainfall amounts. In areas where mean rainfalls are projected to decline, or where droughts are expected to intensify, the vulnerability of water resources in the smaller islands would be expected to be even higher.

[6] The assessment was done using the methodology outlines in UNEP's Handbook on Methods of Climate Change Impact Assessment and Adaptation Strategies.

Box 3.7 Possible Geospatial variables for Small Island Nations

From the discussions in Section 3.3 it is clear that small islands will have some special aspects of vulnerability. These can be expressed in the Geospatial component of the CVI by the following variables:

Extent of land at risk from sea level rise. This could be the amount of land that is less than a certain height (1 m, say) above mean sea level, expressed as the proportion of the total land area. The land area at risk is the zone near the shore, so this variable reflects vulnerability to sea level rise. This factor is sometimes directly related to water resources, for instance, when the land under threat contains freshwater lenses that are used for water supply. However, even when this is not the case, the amount of low-lying land is a major factor in the general vulnerability of small islands. In the worst cases, some of the smallest and most low-lying islands (atolls), this factor could be over-riding with the risk of the near total loss of a nation's habitable land. This variable also reflects the increased vulnerability to tsunamis associated with sea level rise and changing storm intensity.

Population in the zone at risk from sea level rise, expressed as the proportion of the total population. This is complementary to the preceding factor. It reflects the fact that the population, and also infrastructure and economic activity, are not uniformly distributed, but tend to be concentrated in the lower areas. Inclusion of this factor reflects the greater vulnerability that would often occur because of most of the population being in the risk areas. Even islands with mountainous interiors may be found to be highly vulnerable when looked at in this way because people and economic activities are concentrated near the coast.

Isolation index. This is constructed from both the distance to the nearest continental land mass or island group above a certain size, and from the land area of the island (or island group) itself. The smallness of an island gives a measure of the lack of options for water resources. Very small islands, which may be dependent on only a single freshwater lens, are the most vulnerable. Even islands which have conventional surface water supplies are vulnerable because of their small size; any changes are likely to be critical because there may be no other options (e.g. nearby catchments with different resource characteristics) that could be used as a back-up. Similarly distance from other land limits the options both in terms of alternative water resources and economics.

Dependence on water storage. This could be expressed as the amount of storage in relation to the annual demands. As many small islands have limited water resources, few alternatives sources, and may be subject to high degrees of variability, the amount of storage is a good indicator of how they might be able to reduce vulnerability.

Summary - values		R	A	C	U	E	G	CVI
Bahrain	2000	94.2	3.0	13.1	63.6	45.6	54.7	47.0
	2030	**107.8**	**0.8**	**10.2**	**82.6**	**58.2**	**54.7**	**52.7**
Barbados	2000	67.8	0.0	10.2	46.3	45.6	58.7	41.0
	2030	**78.5**	**0.0**	**8.8**	**53.6**	**53.2**	**58.7**	**44.5**
Comoros	2000	69.6	62.0	43.7	57.2	45.6	66.7	58.8
	2030	**84.2**	**15.5**	**31.1**	**86.5**	**58.6**	**66.7**	**58.5**
Trinidad & Tobago	2000	58.0	12.0	23.0	58.4	53.8	44.3	42.0
	2030	**68.0**	**3.0**	**19.7**	**67.5**	**62.8**	**44.3**	**44.2**

Table 3.4 *Preliminary CVI values from national data for some small island States (Sullivan et al, 2003)*

3.6.2 Coastal areas

Low-lying coastal areas are highly vulnerable to climate change and increasing climate variability. They are particularly sensitive to sea level rise and flooding from storm surges. These two impacts are closely linked. Hay (2002) points out that sea level rise will significantly increase the frequency of extreme surge events in countries with low deltaic plains (Bangladesh, the Netherlands, Egypt, etc).

In Bangladesh there are other compounding factors too. Land subsidence means that the global average sea level rise of 1-2mm/year actually means a 4-8mm/year relative rise over the last 22 years in Bangladesh (Hay, 2002). If, due to climate change, the strength of the south-west monsoon increases, Bangladesh's already formidable flood problems will be substantially magnified. Ali and Hoque (1994) show that, for a discharge rate equivalent to the 1988 floods, a 2m/s increase in wind speed almost doubles the amount of water impounded in the country and the backwater effect would result in the water level in the flooded area rising by 22cm in a day. Global warming and El Niño add yet another dimension. Using findings by Emmanuel (1987) that tropical cyclone intensity increases by 10% and 22% for sea surface temperature rises of 2°C and 4°C respectively, Ali (1996) showed that storm surge heights would in turn increase by 21% and 47% leading to inland penetration going up by 13% and 31%.

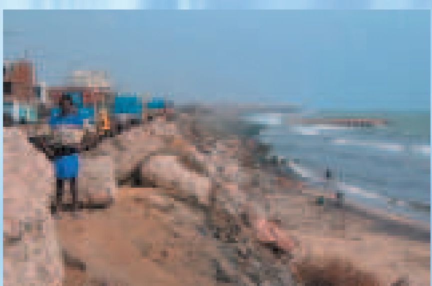
Modelling studies reported by Nicholls et al (1997) sought to estimate how the number of people affected by flooding would rise for a particular sea-level rise scenario. The national-scale model took into account present coastal elevation, subsidence, storm surge characteristics, and trends in coastal population density. The standard of flood protection was represented by using GNP per capita as a proxy. Sea level rise was estimated using the Hadley Centre climate model and ice melt contributions from IPCC (1995, IS92a scenario). That meant a total rise by the 2080s of 44cm. It is important to note that in this model there was no allowance for the type of changes in storm surge frequency or intensity projected by Hay (2002) and Ali (1996).

The results showed that, even without sea level rise, population growth and subsidence would raise the numbers of people flooded each year from 10 million in the 1990s to 30 million in the 2080s. With the 44cm projected sea level rise and no extra flood protection, that figure would grow by a factor of seven to more than 200 million at risk. Increasing flood protection in line with projected GNP growth has a big effect on the numbers, but the number of people at risk still grows to 250% of the 1990 value, meaning 70-80 million at risk. Figure 3.5 shows the coastal areas most at risk.

Box 3.8 A compact overview of coastal zone problems

Ennore creek, Tamil Nadu, India: A compact overview of coastal zone problems. In the foreground traditional fishing boats that operate in the creek. Next dredgers that clear the mouth of the creek from silt that is deposited after a new port was constructed further north. Dredging is required because the new power plant in the background takes its cooling water from the creek. Once the dredging stops water quality problems in the creek build up affecting the fishermen.

The design of coastal engineering works to halt siltation at the mouth of the creek should take into consideration the various users of the creek and its surroundings as well as erosion problems in the vicinity of the creek. An example of which can be seen below.



Chennai, Tamil Nadu, India: Erosion at Royapuram caused by Chennai Harbour. Effects of erosion include the loss of valuable land and coastal infrastructure, the relocation of coastal population and damage to the sewage outfall (in background of the picture). Climate change impacts are likely to aggravate the problems experienced and amplify the call for action

(after S. Werners, 2003)

The rising sea level is also a major threat to coastal wetlands (saltmarshes, mangroves and intertidal areas), submerging them for progressively longer periods in the tidal cycle. There are compensating elements, as greater siltation raises the base level of the wetlands and there can also be an inward migration of the wetlands if the coastal topography allows it. Using the same scenarios as for the flood-risk modelling, Nicholls et al (1997) modelled wetlands losses in relation to coastal morphology and population density. They presumed too that better living standards and care for the environment would bring down present trends of coastal wetland losses from 1% a year in the 1990s to a constant 0.4% a year after 2020. That implied a loss without sea level rise of 37% by the 2080s. The 44cm sea level rise boosts that figure by a further 25%, meaning that approaching half of the world's coastal wetlands would be lost by the 2080s. There is a significant regional variation in vulnerability to wetlands losses. Most sensitive are the Atlantic coasts of North and Central America and the shores of the Mediterranean and the Baltic. The vulnerability comes mainly from their low tidal ranges and limited potential for inland wetland migration.

3.6.3 Megacities

Rapid urban population growth, exacerbated by rural-to-urban migration, is a major developmental challenge for developing countries. In terms of water resources, the escalating demands for water for people, food and industry are frequently made worse by the contamination of available resources that results from inadequate sanitation and wastewater treatment.

We began this chapter by emphasising the special vulnerability of the urban poor to the destructive impacts of storms, floods and droughts. Inadequate basic water and sanitation services and fragile rain-fed farming systems mean that there is very little resilience to climatic extremes.

In 1950 only 18% of people in developing countries lived in cities. In 2000 the proportion was 40%, and by 2030 the developing world will be 56% urban (Brockherrhof, 2000). While urban populations in the industrialised nations are growing at 0.4%, the average growth rate in the cities of the developing world is 2.3%, with Africa experiencing a rate of 4.2%.

The proportion of people living in very large urban agglomerations or 'megacities' (cities of at least 10 million people) is growing all the time. In 2000, 3.7 per cent of the world population resided in cities of 10 million inhabitants or more and by 2015 that

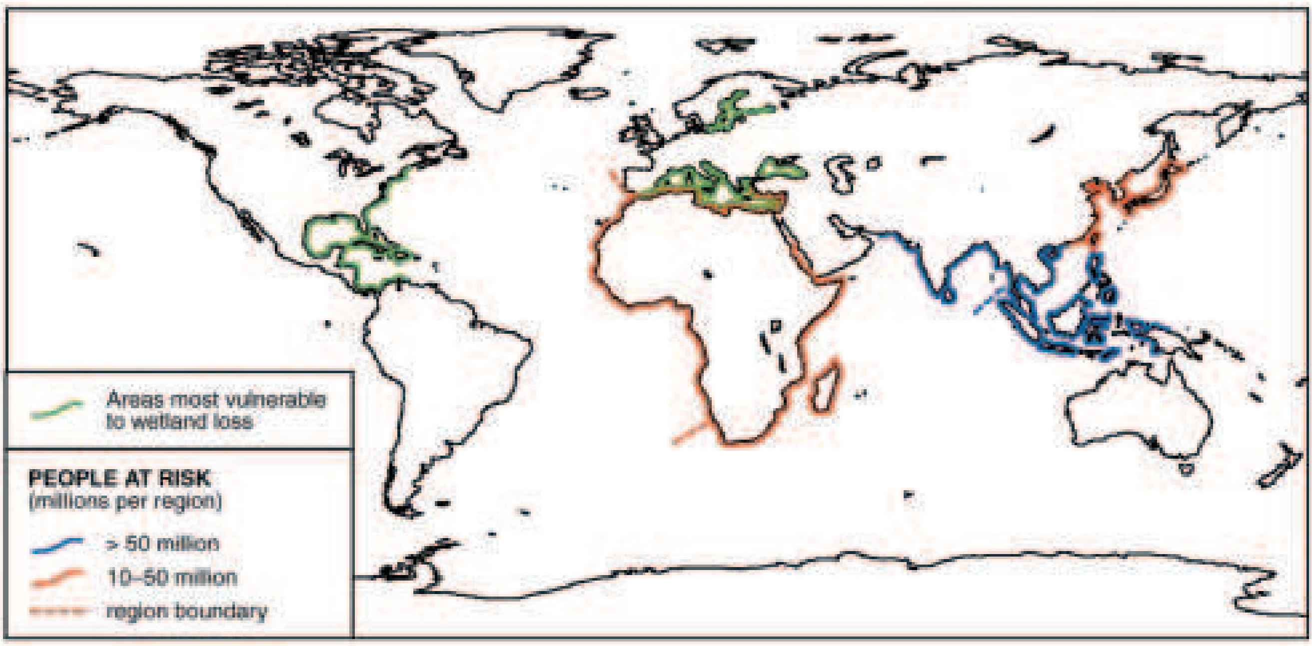


Figure 3.5 *The number of people at risk by the 2080s in coastal regions under the sea-level rise scenario and constant (1990s) protection, showing also the regions where coastal wetlands are most threatened by sea-level rise (Nicholls et al., 1997).*

proportion is expected to rise to 4.7 per cent. Table 3.5 shows that in 1975 only five cities worldwide had 10 million or more inhabitants, of which three were in developing countries. The global number will increase to 21 by 2015, all but 4 of them in developing countries. By then, Bombay, Dhaka, Lagos, and São Paulo will each have over 20 million residents. Also by 2015 an estimated 564 cities around the world will contain 1 million or more residents. Of these, 425 will be in developing countries (Brockherrhof, 2000).

1950		1975		2001		2015	
city	Pop.	city	Pop.	city	Pop.	city	Pop.
1. New York	12.3	1. Tokyo	19.8	1. Tokyo	26.5	1. Tokyo	27.2
		2. New York	15.9	2. Sao Paulo	18.3	2. Dhaka	22.8
		3. Shanghai	11.4	3. Mexico City	18.3	3. Murnbai	22.6
		4. Mexico City	10.7	4. New York	16.8	4. Sao Paulo	21.2
		5. Sao Paulo	10.3	5. Mumbai	16.5	5. Delhi	20.9
				6. Los Angeles	13.3	6. Mexico City	20.4
				7. Calcutta	13.3	7. New York	17.9
				8. Dhaka	13.2	8. Jakarta	17.3
				9. Delhi	13.0	9. Calcutta	16.7
				10. Shanghai	12.8	10. Karachi	16.2
				11. Bunos Aires	12.1	11. Lagos	16.0
				12. Jakarta	11.4	12. Los Angeles	14.5
				13. Osaka	11.0	13. Shanghai	13.6
				14. Beijing	10.8	14. Bunos Aires	13.2
				15. Rio de Janeiro	10.5	15. Metro Manila	12.6
				16. Karachi	10.4	16. Beijing	11.7
				17. Metro Manila	10.1	17. Rio de Janeiro	11.5
						18. Caïro	11.5
						19. Istanbul	11.4
						20. Osaka	11.0
						21. Tiajin	10.3

Table 3.5 *Megacities*

The potential impacts on megacity populations are:

– Increasing water insecurity because of drought or unreliable and/or unevenly distributed rainfall;
– Increasing risks of flooding and water contamination because of more frequent major events like storms and rains;
– Increasing risks of flooding because of increasing sea water level with direct impact in case of coastal cities or inland cities that are located on rivers in the lowlands.

Figure 3.6[7] shows the current level of regional water stress[8] and the location of the twenty largest megacities. In most cases there is a strong correlation between areas with severe water stress and megacities as major water consumers. For megacities in regions already under water stress, future urban growth will be restricted by the limited water availability. Only Lagos, Buenos Aires, and Sao Paulo appear to escape that constraint. To avoid overexploitation of the natural river basins and to provide enough water for industrial and domestic use, most of the megacities import water from surrounding basins, at ever-increasing cost.

Figure 3.7 shows the same areas and megacities but for water stress in the 2020s, under the IPCC A2 scenario, for ECHAM4 climate model. Increases in the regional water stress under this climate change scenario are evident. Also, with the notable exception of Mexico City, the megacities are primarily located on the coast. Depending upon topography and other factors, some of the coastal cities may be particularly vulnerable to sea level rises (see Table 3.6). The case of Buenos Aires is presented in Box 3.9

Vulnerability of the urban poor to extreme events is easy to see, but not so easy to quantify. As we have seen repeatedly in this chapter, modelling future patterns of climate variability is filled with uncertainties. We know where the main risks are and we can be sure that they will increase. For the people involved, that is enough reason to act. As we will see in Chapter 4, when communities are considering how

[7] This map was originally produced for the World Water Assessment Programme by the Center for Environmental System Research, Universiy of Kassel, Germany

[8] withdrawal to availability ratio > 0.4

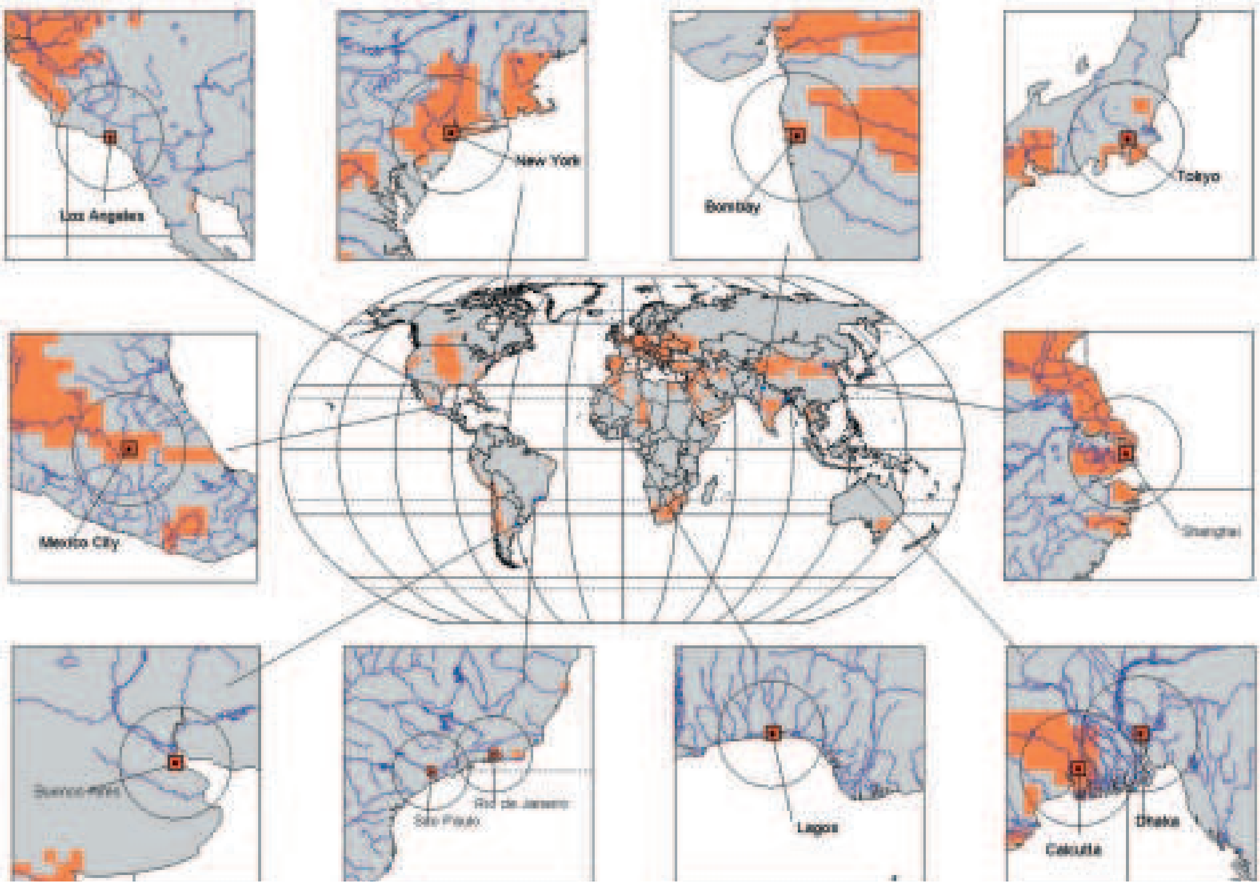


Figure 3.6 *Water stress in regions around selected megacities; current situation (Center for Environmental System Research, University of Kassel, Gemany)*

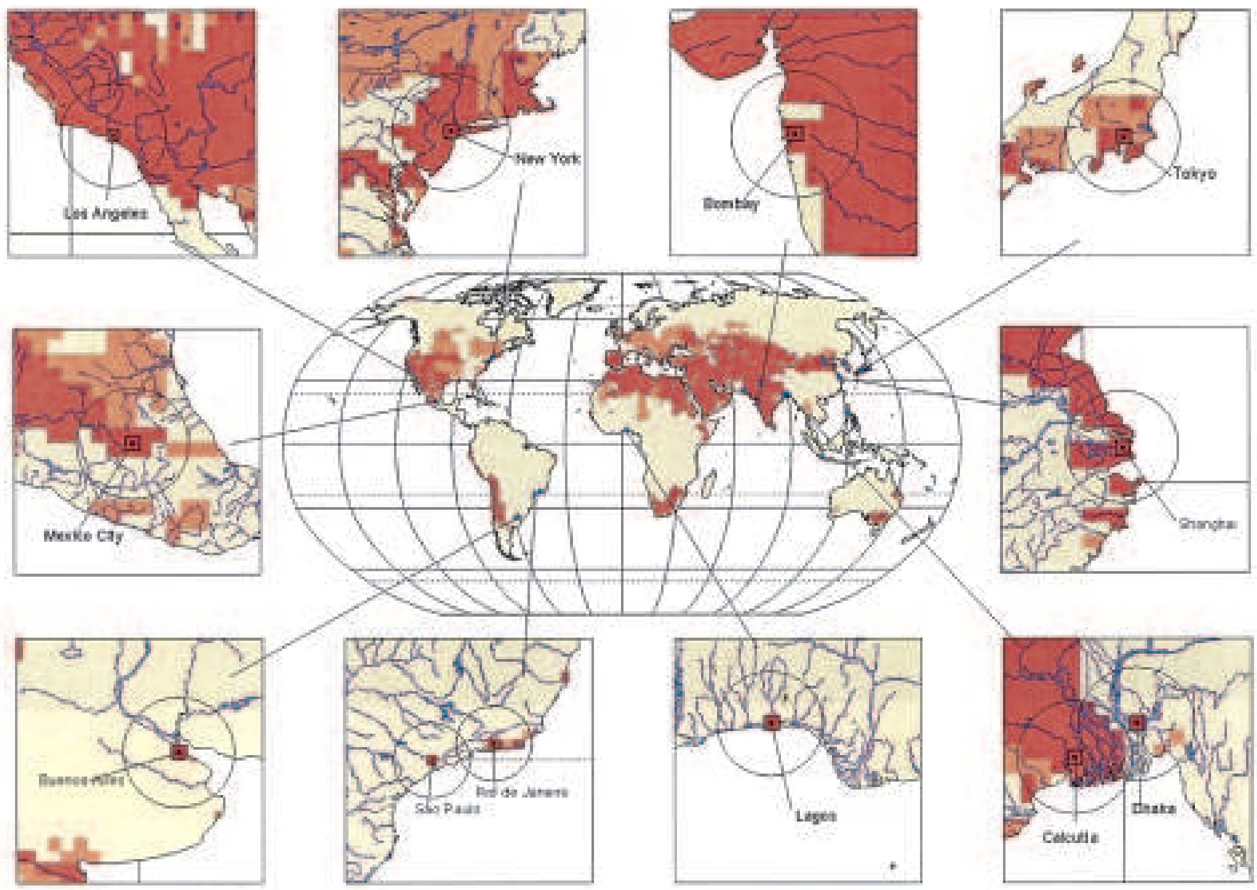


Figure 3.7 *Water stress in regions around selected megacities in the 2020s, under the IPCC A2 scenario, for ECHAM4 climate model in the 2020s SRES A2 (Center for Environmental System Research, University of Kassel, Gemany)*

to adapt to changes in climate, local perception of increasing risk is often more important than scientific proof of vulnerability. Table 3.6 shows the current situation and the climate-related risks for three megacities (Jakarta, Lagos and Buenos Aires). Similar tabulation of risks can be a helpful way of assessing sensitivity to climate change. As the CVI approach develops, it may also be a way of evaluating comparative vulnerabilities from city to city. The first column of the table shows the percentage of households in each city deemed to be below the national poverty line – a proxy for adaptive capacity.

	Households below Nat. poverty line in %	Coverage and types of sanitation	Types of water supply	Risks from climate extremes	Climate change related risks[10]
Jakarta	6.6	3% Central Sewerage; septic tanks; pit latrines	35% of households have piped water, water vendors, deep well water	Storm and flood risks to low-cost housing and water and sanitation systems	Sea level rise; salt water intrusion; high risk of future water stress.
Lagos	53	Public toilet, pit latrine, pour-flush, WC+septic tank; sanitary coverage : 94%	Water sellers, yard taps, Yard wells standpipes, piped indoor	Contamination of water sources and destruction of sanitation infrastructure	Sea level rise; increased flooding, increased rainfall variability; low risk of future water stress.
Buenos Aires	9.5	95% of sewage dumped untreated into river; WC sewerage covers 61%; septic tanks; cess pools	~ 84% piped water; poorer people in peri-urban areas have less connections	Pollution of water sources and associated health risks from floods	Sea level rise, salt water intrusion; increased rainfall variability; low risk of future water stress.

Table 3.6 *Selected coastal megacities vulnerable to sea level rise (after Pahl-Wostl and Ridder, 2003)*

Box 3.9 The impact of climate change on water supply and sanitation of Buenos Aires

The capital city of Argentina, Buenos Aires, currently has a population of approximately 12.1 million people. Buenos Aires is expected to continue growing at a rate of about 0.6 percent per year, bringing population to 13.1 million by 2015 (UNDP). Approximately, 85 percent of Argentina's urban population has access to improved water resources, and 89 percent to improved sanitation facilities. In particular, the peri-urban areas and the poor have to rely on alternative water sources. Uncontrolled sewage and wastewater, environmental degradation and scarce water resources are major issues for Buenos Aires. In addition, as a result of unrestricted groundwater pumping, saltwater has begun to intrude into one of the region's largest reservoirs, the Puelche aquifer. A number of wells have been forced to close. This problem is exacerbated by sea-level rise, which can increase saltwater intrusion, ultimately affecting the supply of freshwater on the densely populated metropolitan area. Despite this, the risk of future water stress in and around Buenos Aires is comparably low due to large amounts of surface water (Rio de la Plata) and the rather low population growth.

Over the past five years there have been major efforts towards decentralisation and privatisation of the water sector. Besides improvements in technical infrastructure, initiatives were also taken to improve service delivery through intermediary organisations targeting low income people[10]. The decentralisation effort brought planning activities closer to the people, aiding in the long-term prospect of sustainability of the projects. Several pilot projects were developed in effort to provide the urban poor with a reliable water supply. These projects incorporated social mapping techniques to determine low income areas and their characteristics. This information was used to adapt the technical design and find solutions at lower costs. Despite these efforts, price increases were high leading to high non-payment rates for water and sanitation. In particular, the urban poor refuse or are unable to pay the high water rates.

3.7 Developmental vulnerability: Millennium Goals

The United Nations Assembly Millennium Declaration of September 2000 included the goal of halving by 2015 the proportion of people who do not have access to, or cannot afford safe drinking water (See Box 3. 10). Recently at the 2002 WSSD, the goal of halving the proportion of people without access to basic sanitation by 2015 was added to the existing Millennium Development Goal for water supply. To meet the Millennium Development Goal water supply target, an additional 1.6 billion people will require access to safe water, and to halve the proportion of people without access to adequate sanitation would require that another 2.2 billion people be provided with facilities by 2015 (Studer, Jamaleddin et al. 2002). These goals present major challenges for all sectors of the international community, and especially those involved in water resources management and the public health community.

The Human Development Report ranks countries by their human development index and by their status in terms of achieving certain Millennium Development targets. However, although a subset of the Millennium targets (namely targets 1, 6 and 7) could be directly or indirectly affected by climatic phenomena, this assessment does not take into account the affects of future climate variability and change. The question is posed: is it likely that the impacts of increased climate variability and change alone will be significant enough to hamper the achievement of the hunger, health and water supply targets (targets 1, 6 and 7) in the year 2015?

As discussed in Chapter 1, little can be said about the magnitude of expected changes in climate variability

[10] http://www.un.org/esa/agenda21/natlinfo/countr/argent/natur.htm#freshw

Box 3.10 Millennium Development Targets (Abridged) (HDR, 2002)

Target 1. Halve the proportion of people suffering from hunger and living on less than USD 1 per day

Targets 2 and 3. Ensure that all people can complete primary education:

2. Net Primary enrolment ratio

3. Children reaching grade 5

Targets 4 and 5. Eliminate gender disparity in all levels of education:

4. Female gross primary enrolment as % of male ratio

5. Female gross secondary enrolment as % of male ratio

Target 6. Reduce under five and infant mortality rates by two-thirds

Target 7. Halve the proportion of people without access to improved water sources

and change by the year 2015. And, factors other than climate change, in particular a reduction in the reliability of the water supply dominated by increases in withdrawals, may in fact have a much larger impact than changes in the vulnerability of the resource. In fact, it would be unrealistic to argue that the magnitude of the mean changes in climate alone will be significant enough to alter progress on achieving the Millennium target of water supply in 2015. Similarly, there is too much uncertainty to determine whether or not the impacts of climate change will reduce the effectiveness of achieving the Millennium hunger target by 2015. However, based purely on development paths, many countries are currently off-track in terms of meeting this objective.

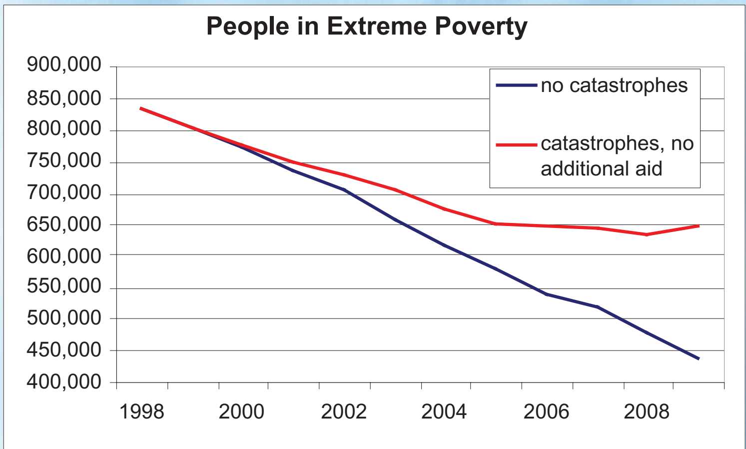
Regardless of whether or not recent changes in climate variability and in the magnitude and frequency of the extreme climate events can be attributed to climate change, an increase in the frequency and intensity of extreme events is being observed (Chapter 1). Evidence suggests that even small changes in the magnitude of extreme climate events have an exponential effect on losses. As illustrated by an example in Box 3.12, these types of changes could have a seroius impact on development agenda and could therefore derail the achievement of any number of the Millennium targets.

3.8 Conclusions: The limits of top-down assessments

Most vulnerability assessment methodologies described in this chapter are representative of a "top-down" approach. The aim of this type of approach is to provide a comparative overview of regions that may require special attention from the research and development assistance community, under particular scenarios. There are, however, several problems

Box 3.11 The Impact of Natural Catastrophes on Number of People in Poverty in Nicaragua

The blue line in the figure shows the current policy objective for Nicaragua: to reduce the number of people in extreme poverty. Those individuals living in extreme poverty are living on less than USD 1 per year. The Millennium target for poverty is to halve the number of people living on less than USD 1 per day by the year 2015. The blue line indicates that, in the absence of a catastrophe, GDP growth alone reduces the number of people in extreme poverty by 400,000 people by the year 2009, putting Nicaragua ahead of schedule in terms of achieving the Millennium target by the year 2015. Analysis of the expected impact of the aftermath of the 1998 Hurricane Mitch catastrophe on the number of people living in extreme poverty (shown by the solid line), indicate that for the decade following the catastrophe the number of people in extreme poverty remains relatively high. In fact, the impacts on the poor may be even higher if the poor suffer a disproportionate burden of the losses, as expected. A major issue in this analysis is the incorporation of natural catastrophes into broad planning. To avoid the outcome described by the red line in the figure, Freeman and Warner (2001) stress that the impacts of natural catastrophes on the poor need to be taken into consideration, and that more assistance than is currently planned will be required in order to meet poverty reduction goals in the event of a catastrophe. Thus, considering catastrophe impacts and poverty in broad planning activities could help Nicaragua achieve its poverty reduction measures, even when a catastrophe occurs. If the impacts of natural catastrophes are not considered, when a catastrophe occurs, Nicaragua will not achieve its poverty reducing objectives.



Changes in extreme poverty with and without the 1998 Hurricane Mitch catastrophe (Freeman and Warner, 2002) associated with global, top-down vulnerability assessments.

First, the resolution scale of most global analyses is often too large to be used in identifying smaller areas that may be highly vulnerable, such as small islands and coastal areas. Second, although they use the same basic assumptions linking vulnerability to capacity and development levels, they generally fail to encompass all of the main impacts of climate change, and especially climate variability. As a result, for example, Bangladesh, which has long been recognised as a "climate change hot spot", does not appear to be highly vulnerable under the majority of scenarios presented above. Third, these assessments are often based only on projections of average climate conditions (e.g., average annual precipitation). In reality, climate variability poses a much greater threat to water managers than do long term trends. Finally, the outputs (maps) from these global analyses can detract attention from highly vulnerable areas that may have been missed.

Indeed, the vulnerability of water resources is primarily manifested at the basin level – and that is where the primary adaptation efforts must be aimed. It is also at the community level that people are most aware of the most appropriate adaptation measures. As will be shown in the following chapter, awareness among stakeholders is high and is growing rapidly.

"Top-down" methods are therefore best seen as a type of sensitivity analysis that can complement "bottom-up" studies of the vulnerability of particular watersheds.

Chapter 4: Coping Actions

Figure 4.1 *The 18 Dialogues, initiated in the first half of 2002, covered a wide range of climate-related hazards. Their activities have yielded a "Compendium" of coping options (Table 4.1 opposite).*

4.1 Stakeholder Dialogues

It is clear from chapters 3 and 4 that responses to the impacts of climate variability and climate change involve coping actions at many different levels. Internationally, treaties, conventions and global accords are the foundation for concerted action to mitigate global warming. Regional cooperation and transboundary agreements provide a basis for better management of international rivers to prepare for and alleviate extreme events. Information sharing, early warning systems, climate forecasting and modelling all help water managers to prepare coping strategies. But it is on the ground, in the individual river basins and communities, that the vital coping actions have to be taken. In this chapter, we focus on the wide range of local actions that are helping committed stakeholders to protect themselves from the worst effects of our changing climate. The strong message going out to governments, donors and disaster relief agencies is that locally planned, locally managed adaptation to changing climatic circumstances is practical, beneficial and cost effective.

What is new about today's challenges is the increasing variability in climate, coupled with the certainty that extreme weather events are going to keep occurring. So, water managers can no longer rely on infrastructure and operating rules designed on the basis of historic climate records. They need new data, new predictions and new calculations. For that, they also need closer contacts and stronger working relationships with the climatologists, meteorologists and hydrologists who monitor and interpret climate oscillations, ocean temperatures, rainfall and runoff records.

Not all water managers have recognised those needs. Even those who have may find it difficult to get the right type of information from the climate sector, to suit their planning needs. It was this gulf between the two professional communities that prompted the establishment of the Dialogue on Water and Climate (DWC). DWC's mandate was to build bridges between water managers and climate specialists and to foster cooperation at all levels.

> ***" . . . locally planned, locally managed adaptation to changing climatic circumstances is practical, beneficial and cost effective."***

In the first half of 2002, DWC initiated 18 stakeholder dialogues to assess and prepare responses to the water/climate situation in different parts of the world. They range from community to subcontinental in scope and are located in both developed and developing countries. Eight of the 18 are categorised as "Basin Dialogues", their focus being a particular river basin; two are "National Dialogues"; the remaining eight are described as "Regional Dialogues", and involve more than one country. Between them, they cover a wide range of situations that are most vulnerable to climate variability and anticipated climate change – small islands, low-lying coastal areas, flood-prone and drought-prone regions, and territories subject to hurricanes, typhoons and storm surges. Participants in the Dialogues include water professionals, community representatives, local and national government, NGOs, national and international knowledge institutions, researchers, climate specialists, and others sharing an interest in developing responses to climate-related threats. To complement the dialogues, DWC also commissioned 20 Thematic Papers by recognised experts, exploring key water and climate issues ranging from climate change scenarios to gender

ADAPTATION OPTIONS	DRAWN FROM DIALOGUE(S)
POLICY INSTRUMENTS	
International	
International Conventions on Climate Change	Caribbean, Pacific Islands, Mediterranean, Southern Africa, West Africa, Central America, Netherlands, Bangladesh
International policy - to mitigate or to adapt?	Netherlands
International Trade (particularly WTO)	Mediterranean, Bangladesh
Polluter-pays principle influences ODA/Funds	Southern Africa
Regional	
Regional Adaptation Plans of Action	Southern Africa, West Africa, Caribbean, Central America, Mediterranean
Regional Strategic Action Plans for IWRM	Southern Africa, West Africa, Pacific
Transboundary plans and interstate cooperation	San Juan, Aral Sea, West Africa,
Informal bi-national cooperation	San Pedro
Regional institutions	Caribbean, Small Valleys Programme
National	
National Poverty Reduction Strategies	Thukela, West Africa, Southern Africa
National strategic interests	Lena
National Water Policies and Laws	Thukela, Lena, Yellow River, Bangladesh, Netherlands
National Adaptation Plans of Action	Bangladesh
Disaster Management Policies	Bangladesh
National Drought Action Plans	Murray Darling
Economic instruments and water markets	Murray Darling, Yellow River, Aral Sea
Risk management cross-cutting in development plans	San Juan, Bangladesh, Pacific, West Africa, Netherlands
Strengthened functions of River Basin Authorities	San Juan, Thukela, West Africa
Integrated catchment management	Murray Darling, Yellow River
Water management strategy under climate change	Lena
Non-water planning, eg urban areas, refuges	Nagoya
TECHNOLOGICAL AND STRUCTURAL INSTRUMENTS	
Storage and Reticulation	
Surface water	
Large Reservoirs	Nagoya
Small Reservoirs	*
Groundwater	
Artificial Recharge	*
Borehole Drilling	*
Sand Dams	*
Scavenger/Gallery Wells	*
Related options	
System Maintenance	
Supply Leakage Control	*
Irrigation equipment maintenance	*
Irrigation Canal Leakage	*
Rainwater Harvesting	Nagoya, Caribbean
Water Re-use/Recycling	Mediterranean, Bangladesh, Yellow River, Nagoya, Aral Sea
Desalination	Caribbean
Flood/Storm Surge Control	
Structures (Levees, Dykes)	Netherlands, Bangladesh, Nagoya
Preventative operations	Lena
Early Warning Systems	
Near Real Time (Hours to Days)	Bangladesh, Small Valleys Programme, Nagoya, West Africa
Short-Term (Days to Weeks)	Bangladesh
Medium-Term (Month to Season)	West Africa, Southern Africa, Pacific
Long-Term (Years to Decades)	Caribbean, Pacific
Communicate Forecasts to End-Users	Mediterranean, Netherlands, Thukela, Bangladesh, Nagoya
Operations/System Improvements	
Reservoir Operations Rules	Nagoya
Integrated, optimised reservoir systems	Nagoya
Retrofitting Existing Structures	*
Irrigation scheduling	Murray-Darling
Water Demand Management	Mediterranean, Bangladesh, Yellow River, Nagoya, Aral Sea
Indigenous Coping Strategies	*
Precipitation Enhancement	*

ADAPTATION OPTIONS	DRAWN FROM DIALOGUE(S)
RISK SHARING AND SPREADING	
Insurance	
Primary Insurers	Caribbean
Re-Insurance	*
Micro-Insurance	*
Finance	
Development Banks	*
Private	*
Micro-Lenders	*
CHANGE OF USE, ACTIVITY OR LOCATION	
Land Use Measures	
Conservation Structures	
Adaptive Spatial Planning	Nagoya
Tillage Practices	
Crop varieties	San Juan
Resettlement	

ADAPTATIVE CAPACITY	DRAWN FROM DIALOGUE(S)
KNOWLEDGE, SKILLS AND PARTICIPATION	
Participatory Approaches in Decision-Making	
Stakeholder Dialogues	All
Awareness raising	San Pedro, Lena, Nagoya
Stakeholder surveys	Bangladesh, San Pedro, San Juan
Networks of action	Small Valleys Programme
Advocacy through stakeholder River Basin Committees	Thukela, San Pedro
Knowledge Consolidation	
Common adaptation frameworks	Mediterranean
Piloting adaptation options	West Africa
Baseline studies	Nagoya
International information sharing	Bangladesh, Pacific, Caribbean
Integrated information systems	Yellow River, Aral Sea
Research and Development	
Improved climate modelling	Yellow River
Integrated science programmes	Murray Darling, Yellow River
Integrated management tools with climate embedded	Murray Darling, Aral Sea
Risk mapping	Netherlands, Mediterranean, Caribbean
Observation of basic data	
More intensive observation systems	Nagoya, Lena
Skills	
Technical and operational capacity	Southern Africa, West Africa
Forecasting	Small Valleys Programme
Drought Resistant Crops	Mediterranean
Specific skill needs	Caribbean, Small Valleys Programme

MITIGATION OPTIONS
REDUCING EMISSIONS OF GREENHOUSE GASES
Energy
Energy mix
New sources of energy, (low-carbon and renewables)
Energy conversion technologies
Energy demand management
Technological
Improved efficiency of end-use devices
Reduction of industrial by-products
Reduced process-gas emissions
ENHANCING CARBON SINKS
Conserving the existing carbon pools
Increased sequestration through new carbon pools
Substitution of sustainably-produced biological products

*denotes options originating from sources other than the 18 Dialogues.

Table 4.1 *Compendium of Coping Options* considerations in adaptation. Five case studies and four commissions for toolkit development completed the DWC-sponsored activities. Annex 1 contains a full listing of dialogues and themes and the topics they addressed. A CD-ROM included with this report contains details of the Dialogues, abstracts of the Thematic Papers and a Bibliography.

Each of the 18 dialogues had its own, often very specific objectives, but they had several things in common. They all set out preparing a state-of-the-art type document about water and climate. Some focused on model-based forecasting, others on investigating local perceptions at village level. Some brought together the science community and water managers, others had more NGOs involved. For most dialogues it was a first initiative to address water and climate issues, but most worked determinedly towards an action agenda for adapting to climate-related problems.

The results have been substantive and wide-ranging. Despite less than a year of activity, the dialogues have proved to be an effective way of advancing both thinking and action. They have shown, for instance, that scientific studies on vulnerability to climate change or climate variability are not the deciding factor influencing the people involved at local level. Indeed, the village level studies in Bangladesh revealed that villagers are well aware that weather extremes are becoming more frequent and more intense. They have seen the destructive power of storms, floods and droughts. They recognise the urgency of learning to cope with the new circumstances. And, crucially, when they meet in the focus-group atmosphere of a water-and-climate dialogue, their brainstorming comes up with effective and sustainable ways of combating the causes and the effects of hydro-meteorological disasters.

The outcomes of individual dialogues are summarised in the "yellow pages" of this chapter. Fuller reports are available from DWC and they can be viewed or downloaded on the DWC website (http://www.waterandclimate.org). In a number of cases, such as Bangladesh, the Netherlands and Nagoya, coping actions were already under way when the Dialogues began; in others they are in the planning stages (Western Africa, Mekong) and others again are still in the initial awareness raising stages (Southern Africa, Aral Sea, Lena basin). Encouragingly, all have internalised water and climate as an issue to be addressed at the basin, regional or national level. Nevertheless, any comprehensive programme to cope with climate variability is sure to require co-operation and support from outside agencies, and that is the subject of Chapter 5.

4.2 A Coping Compendium

DWC supplemented the Dialogues with thematic studies about livelihood impacts (social, economic, institutional, health and environmental) and others evaluating different coping actions. The wealth of water-and-climate literature that has been published in recent years was also consulted. Combining the Dialogue results, the thematic studies and the literature review led to a "menu" of options from which water managers can identify the most appropriate for their own circumstances.

The menu is presented in Table 4.1 opposite as a first "Compendium" of coping actions. It is a long list and includes necessarily cryptic descriptions of activities such as "water demand management" and "large reservoirs" that are obviously already part of the water manager's armoury. By cross-referencing the actions to specific dialogues, the Compendium provides its users with real examples of how adaptation has worked in practice and hence to the special climate-related criteria applying to the option concerned. So, for instance, the "large reservoirs" option is linked to the Nagoya Dialogue (see yellow pages), in which the recent extreme floods and droughts have meant new rules for integrated management of existing and new storage facilities.

The Compendium is a first effort and does not cover every circumstance or potential remedy yet. It is DWC's hope that it can become the basis for a comprehensive dossier of case studies and applied research. In that way, it can develop into a handbook for practitioners and a start-up tool for future water-and-climate dialogues seeking to develop coping strategies. Readers of this report are encouraged to supplement the Compendium with their own experiences of coping options, and to help build the dossier of case studies. Follow-up activities will also include converting the variety of experiences from the 18 Dialogues into guidelines for initiating and operating multi-stakeholder dialogues at basin, national and regional levels.

4.3 Lessons from the dialogues

4.3.1 The power of partnership

The 18 Dialogues brought together groups of stakeholders linked by their concern about water and climate. Most have decided to continue their work. The shared commitment and combined expertise built a mood of urgency and a capacity to find practical adaptation options as a basis for action plans

This is strong argument that the Dialogue model in principle provides a successful mechanism for a basin, a region or a country to develop a strategy and action plan for coping with climate variability and climate change.

4.3.2 Perceptions of vulnerability

Chapter 3 illustrates some of the efforts being made to categorise regions or countries or even locations (cities, wetlands or small islands) according to their vulnerability to climate. It concludes that there are few proven ways yet to compare vulnerability at the local level. Although the scientific tools may not be available, the Dialogues are showing that it is perception rather than proof that motivates people to act. Whether a country's vulnerability to climate is ranked 5th or 150th in the world does not appear to matter; it is local concerns that set local priorities. A high vulnerability ranking may be important when there is competition for financial support (see Chapter 5), but the inability to produce league tables is not a deterrent to local action.

4.3.3 Basin Dialogues

Eight of the 18 Dialogues were based on river basins (San Juan, San Pedro, Thukela, Lena, Murray-Darling, Yellow River, Nagoya, Small Valleys). In all but one (Thukela, which does not have a basin authority), it was the river basin authority that led the Dialogue. These basin-level Dialogues proved to be very participatory, informal and transparent. They brought together local stakeholder groups, including climate and water scientists, farmers' associations, NGOs, municipal authorities, trade unions, and school teachers. To these are added representatives of state/provincial and national governments, agency officials and academics.

The Dialogue structure at this scale has allowed for great flexibility and led to considerable penetration of the issues among community members. At least two of the Dialogues - San Juan and San Pedro – have been able to draw on earlier community surveys. These had already helped to raise awareness of water-and-climate issues, and provided a cross-section of stakeholder concerns and opinions. Some, such as Murray-Darling and Nagoya drew on earlier scientific work and others (Lena and Aral Sea) developed their own scientific base for water and climate. The Small Valleys dialogue was used to initiate the setting up of an NGO for village-based early warning and disaster preparedness.

Some useful common conclusions can be drawn from the eight Dialogues:

1. All the Dialogues will continue developing their discussions into concerted local action by concerned communities and by local authorities. In some instances, follow up actions are already in place (Small Valleys, Nagoya); in others they are being planned.
2. None of the Dialogues are responding to a discrete and definite projection of climate change. There is a sense that the jury is still out on the case, and that impacts expected in 2025 and after do not feel

like immediate and pressing problems. Some have been moved to act because mounting pressures on water are affecting their daily lives and climate is just one factor among many. Most are adapting because they have sensed that the climate and water situation has already worsened locally. This may have been triggered by a one-off incident, such as Hurricance Mitch, or by the threat of a major incident, but usually it is simply a sense that there is now a greater incidence of disasters. It is not always the extreme events that are of concern – it is the unrelenting sequence of disturbing weather that causes disruption to livelihoods and creates a sense of foreboding. The Dialogues may sometimes seek out evidence from the formal observation networks and from the professionals to substantiate the case for action, but that does not seem to be as important as a wider, unqualified sense of change.
3. All the Dialogue basins have already lived with variability, and society and systems have learned to cope with it. Their concern is to be prepared for extremes that are increasing in frequency and scale.
4. The Dialogues have pursued different processes and channels to develop their coping strategies. The organisational frameworks include volunteer-based NGOs focused on urgent action on a specific problem, and an "Exploratory Committee" to capture knowledge and to make recommendations. Both of these have targeted the climate problem directly. Other dialogues have sought to influence the actions of existing community-based river basin committees, and government-linked river basin organisations, urging that they address climate issues in their day-to-day water management. The lead role of the basin authority is clearly a help here. The fact that the authorities have control of basin policy and integrated water resources management (IWRM) strategies means that they are well-placed to implement coping actions arising from the Dialogues.
5. The Dialogues are developing in parallel with national strategic approaches. Either national strategies are not yet in place, or else local action is

Summaries of Basin Dialogues

San Juan

The San Juan is a boundary river between Costa Rica and Nicaragua, with one million basin inhabitants. It is rich in biodiversity, but most of the people live in poverty and lack access to safe drinking water, adequate sanitation, and schools. The Costa Rica portion is the more developed of the two but all economic and quality-of-life indicators in the basin are significantly below the national averages in both countries.

Poverty is exacerbated in the basin by hurricanes and tropical storms, lying as it does on the westward passageway for anticyclones from the Atlantic to the Pacific. Climate variability has long been manifest through a succession of floods, droughts and intense rainfall. In August 1997, floods in the southern portion of the basin caused five deaths, 1,000 homeless and losses of US$12 million. Also in the southern sector, the 1997/98 growing season saw 80% of grain and 60% of root and tuber crops lost to drought, with a further loss of 700,000 quintals of corn in the north. Two thousand head of cattle perished.

These climate impacts are on top of the threats posed by volcanic activity and seismic pressures that already make the freshwater supply very vulnerable. Basic services are strained further by inward and north-south migration from Nicaragua, responding to higher social deprivation and abnormal weather events. In September 2001, 70% of the immigrants crossing into Costa Rica through San Carlos in Nicaragua were motivated to relocate by that year's drought. Reducing vulnerability to climate variability and change is crucial to the people's aspirations for a future of sustainable social and economic development.

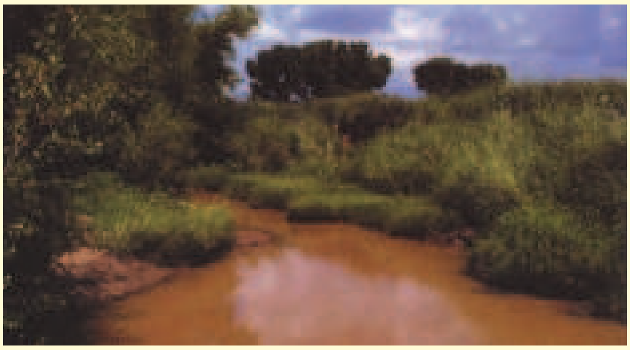
The mechanism through which the stakeholders of the basin are beginning to channel their action to cope is the PROCUENCA-SAN JUAN. This is a participatory basin association, authorised and executed through technical units of the two Governments.

The Dialogue participants recognised that steps already taken were proving useful in confronting climate variability. These include use of improved crop varieties adapted to the shortest cropping cycles. Use of crop wastes as organic fertiliser has reduced the amount of waste transported by intense rainfall to water bodies. The food-for-work program has assisted families severely affected by drought and other disasters. One measure not yet in place, but seen to be of value, is an inventory of wells and boreholes that would facilitate quicker responses.

Pursuing the action to cope to its recommended end-point will see a number of outcomes in place:

- a strategic plan for disaster prevention and mitigation (paying attention to transboundary emergencies),
- better territorial planning,
- risk management becoming a crosscutting issue in development planning (particularly in the important tourism sector),
- active Basin Committees that conserve and manage the water resource endangered by climate variability, and
- enforced legislation on disaster prevention and mitigation based on local realities

San Pedro (USA/Mexico)



The San Pedro basin contains one of the last naturally flowing perennial rivers in the arid south-west of North America. It creates a riparian habitat in the midst of the desert – a resting ground critical to several of the hemisphere's rare migratory birds. The river flows north from Sonora (Mexico) to Arizona (USA), draining 12,000 km^2. The Arizona portion is heavily dependent on groundwater supporting ecosystems (44%), agriculture (30%), industry (17%) and municipal and domestic uses (9%). In Mexico, the river irrigates 3400 ha, and the two urban areas of Cananea and Naco draw groundwater for residents and for North America's largest copper mine.

Aridity limits sustainable growth and complicates the protection of natural areas. The two widely disparate economies and societies share the common challenge of environmental management. The chief driving forces are rising manufacturing in Mexico and rising population in the U.S. Key environmental issues of the basin are, in priority order: competition from depletion of the transboundary river; climatic problems (drought, warming, flooding, monsoon onset and duration); the problem of toxics; and the challenge of maintaining ecosystems. Climatic variability and change further stress the system at a time when binational obligations constrain both nations in their responses to the climate crisis.

Initial interest in the Dialogue lay in the opportunities for binational information exchange on scientific research. Wider interest has grown from the Dialogue, and other informal co-operation is emerging among local agencies and NGOs . The Upper San Pedro Partnership in Arizona has repeatedly intended to meet with the Asociación Regional Ambiental de Sonora-Arizona (Sonora-Arizona Regional Environmental Association or ARASA). ARASA already includes Arizona residents among its members and has expressed a desire to discuss water and climate issues with the Partnership. The Dialogue coincided with the Partnership's formulation of a new water conservation and management plan, including allocation for the San Pedro Riparian National Conservation Area in southeastern Arizona. At the same time, the Sonoran towns of Naco and Cananea face decaying water infrastructure and delivery problems, as well as the challenge of maintaining and building adequate sanitation facilities. The basin is currently being developed outside the national strategic planning process. All the basin Dialogues recognise the need to mainstream their actions into or be part of national strategies.

6. Mitigation has figured low in the coping agenda at this level. It is, of course, a national and international issue, but it is significant that the basin Dialogues do not generally see a need to call for mitigation measures to accompany their local adaptation.
7. The Dialogues show some evidence of a human focused protective approach (Small Valleys), but not overwhelmingly so. Ecosystem protection also emerges as a priority (Lena).
8. Self-help, bottom-up adaptations have usually been the starting point, but the Dialogues have been careful to engage with local and national government from the outset. This approach has enabled stakeholders both to take direct action and to influence higher-level decision-making – particularly in the case of transboundary basins, where the facilitating nature of the bottom-up basin dialogues has been a spur to cross-border action. As many of the adaptation actions proposed but not yet implemented extend beyond the community and call for action to be taken on their behalf at higher levels, the fostering of links with authority is seen as a fundamental principle of basin-level Dialogues.
9. Although the coping actions developed through the basin Dialogues have a strong local focus and build on local adaptive capacity, the strategies in the developing countries inevitably will require a degree of external support. All the dialogues adopt the principle that prevention is better than cure and that pre-emptive investment in adaptation ahead of disasters will mean less destruction and less demand on humanitarian relief afterwards.

4.3.4 National Dialogues

There were only two National Dialogues – in Bangladesh and The Netherlands and they were very different in both scale and purpose. The Bangladesh Dialogue was very complete in its scope. Its activities included perception studies at village level in seven hydrologic regions, village-level livelihood impact studies, as many as 10 diverse sectoral impact studies on topics such as agriculture, forestry, ecosystems, biodiversity, policy level discussions up to ministerial level and inclusion of the outcomes into the National Adaptation Programme of Action (NAPA) under preparation.

In the Netherlands, the aim was to consolidate in a single publication the science and operational knowledge and the policy developments of a country which is highly susceptible to increasing climate variability. The process of evolving from a philosophy of battling against water extremes through protection

measures (dikes and dams) to "Living with Water" is being documented and revealing lessons about approaches and actions at national and local levels. The Netherlands Dialogue also links into a recently started public and policy debate about the potential role of risk spreading and public acceptance in addressing the impacts of extreme events.

From a base of just two Dialogues with very different circumstances and approaches, it is not wise to make too many generalisations. Some conclusions though may be helpful for other countries wanting to establish National Dialogues:

1. Though these two may not be typical, it has been extreme events – or the fear of extreme events – that was the most significant trigger to action at national policy level. Headline-making disasters moved the national consciousness forward further than the sum of many smaller events.

experiencing severe drought, impeding the capacity of farmers and ranchers to maintain their traditional lifestyle, on both sides of the border.

Amid this urgency, Dialogue partners are assessing information needs, identifying regional vulnerabilities, promoting water-and-climate-management strategies, and increasing binational organisational and institutional co-operation. Education and awareness raising among the youth is proving successful in both countries. Learning from fields trips to the river and school classes on nature, the youth are bringing the messages home to their parents. The Dialogue activities have meant that more interactions will be scheduled than were originally intended.

Thukela

The Thukela basin in South Africa is diverse socially, economically, climatically, ecologically and hydrologically. The basin is characterised by intensively developed commercial dryland and irrigated agriculture and by severely degraded rangeland areas with subsistence agriculture. The latter areas are home to a poor population, many of whom lack formal water supply services. The catchment is subject to highly variable inter-annual rainfalls and runoffs. Severe droughts of several successive years' duration occurred in the early 1960s, 1980s and 1990s, while extreme floods have also ravaged the catchment several times. Indicators of climate variability show the basin, particularly its water-poor rural communities, to be very vulnerable to prolonged droughts and extreme flows – a situation which is likely to be exacerbated by future climate change. It is in this environment that the national water agency, bulk water suppliers, municipalities, riparian owners, farmers and the vulnerable poor rural communities have to deal with short-term climate variability and long-term climate change, amid the context of integrated water resource management and many people-centred challenges.

The recent National Water Act (1998) of South Africa designated the Thukela as a Water Management Area (WMA). This means that, in time, the peoples of the basin will be responsible for their own integrated water resource management through a Catchment Management Agency (CMA). The Dialogue in the Thukela helped brought together the different water sub-sectors, technical service providers and practitioners, scientists and managers, practitioners and end-users, scientific know-how with indigenous knowledge, and biophysical scientists and human scientists. The central point of action arising was the continued development of an installed hydrological modelling system for applications in risk management. This is being pursued in a wider context in which integrated science serves an emerging economy to develop, to sustain and to maintain.

Lena

The Lena River of eastern Siberia is among the ten largest rivers in the world. At 2.5 million km^2 the basin is twice the size of South Africa and four times the size of Texas, and has one of the most severe climates in the world. Up to 35% of the annual flow occurs during just a few weeks of spring flooding. Catastrophic floods are caused by the combination of more intensive snow cover melting (due to climate warming and increased winter precipitation), and large ice jams in critical locations (Srednekolymsk, Yakutsk, and Lensk). Without ice jams, peak water levels seldom exceed 5-8 m over the average, and do not pose a particular threat. But the combination of high spring discharges and ice jams brings catastrophic floods, bringing water levels 15-20 m above average, particularly in the lower Kirenga, Olekma and Aldan.

In recent years, floods have been more extreme and have occurred earlier in the season. Prior observation and research has created a solid basis for understanding climate change impacts on water resources. However, climate change and variability are not yet fully considered in decision making, due to weak communication between the hydrological and meteorological science communities, and between water managers and politicians. Inadequate water management and emergency protection measures have led to significant economic and social losses in recent years.

The Dialogue focused on action-oriented outcomes. Recommendations were made to the State Hydrological Institutes on how to improve information dissemination. The Lena Basin Water Management Authority was urged to complete an inventory of water management facilities in the Lena basin. The participants saw a need to formulate a strategy on water resources management and flood preparedness under climate change.

Recognising the significant threat from catastrophic floods due to ice jam formation, the State Hydrological Institute was encouraged to continue its work in this area based on latest scientific findings, and the Ministry of Civil Defence and Emergency Situations of the Republic Sakha (Yakutia) to find opportunities to finance these works. Long-term measures include bottom deepening, river bed straightening, and ice controlling operations. These measures were actively introduced between 1960 and 1980s, but transition within the Russian Federation meant that activities were drastically reduced in the 1990s. This led to gradual shallowing of shoals, narrowing of main river channels, and destruction of water management facilities. The participants considered that construction of a new hydro-power station upstream of Lensk would make a significant contribution to ice control. Operational preventative measures are aimed at reducing ice stability prior to break-up,

2. For both Bangladesh and the Netherlands a lot was already known and done in the water sector to cope with climate variability and even anticipated impacts of climate change. The high level of information, knowledge and expertise distinguishes these two National Dialogues.

3. The Dialogues raise an interesting issue about embedding climate and water issues into national policy. Is it more effective to ensure due and proper consideration of climate issues into the national policies on sectoral themes, or to pursue a separate climate and water policy? It would appear that the common issues can be established in a cross-cutting climate-and-water strategy, but that the sectoral policies (water, disaster, agriculture, environment etc.) may offer the greater prospects of translating them into operational practice. There is a problem with this approach though. Unless it is central to their day-to-day functions, implementation of climate-related activities may not gain the right priority. Getting climate issues into sector programmes certainly oils the wheels, but concerted implementation is complicated by needing to achieve the same in many sectors, and to bring the many together with a common purpose.

4. Despite the prospects that sound policy can offer, there is undoubtedly a challenge in moving from policy on paper to implementation of policy on the ground. The NAPA is thought to be a useful vehicle for moving forward with strategic planning in Bangladesh. Policies may be in place, but it is the move to implementation that tests their adequacy, and gaps are soon detected. There is a strong pragmatism in the approach of focusing on what can be done immediately.

4.3.5 Regional Dialogues

There were eight Regional Dialogues: Aral Sea, South Asia, Central America, Caribbean Islands, Pacific Islands, West Africa, Southern Africa, Mediterranean. Regional Dialogues provide an opportunity for people and institutions from neighbouring countries or with similar geographic features to discuss the outcomes of long-term regional outlook studies and set up regional information systems, find common solutions, and develop regional strategies. Many international organisations involved in water and climate, such as IUCN, GWP, and several United Nations programmes, have regional offices across the world. They also have a proven ability to bring together a broad range of stakeholders to participate in dialogue activities, and this was mobilised to establish several of the Regional Dialogues. The regional scale also proved to be of interest to the international climate and meteorological community. Seasonal forecasts are issued at the regional level, and most areas have regional meteorological offices tasked to pass climate forecasts to national governments.

From a base of eight Dialogues, these are the issues that seem to be most common at the regional scale:

1. Approaches at this scale are characterised by programmes of action that are broader in scope than those at community and river basin scale. There is evidence that the 'view from the top' looks more fully across the range of sectors. There is also evidence of integration, or desire to integrate, the regional climate programme with other region-wide water programmes, and standing Conventions.

2. Equally, and understandably, it is clear that there is some considerable distance from the issues and immediate action on the ground that emerged so strongly from communities and river basins. The regional programmes are oriented less towards specific actions that respond to specific circumstances – rather, they are directed towards creating an enabling environment at a wide multi-country scale. To be most effective they need to be complemented by national and/or basin dialogues.

3. The general approach for Regional Dialogues is the development of regional adaptation strategies, advanced on the principle of subsidiarity and complementarity with NAPAs. Most of the Dialogues imply that formulations remain at an early stage, and entail further development of the adaptation framework.

4. Regional Dialogues can offer economies of scale in several areas: by supporting several countries simultaneously in the setting of their strategic direction; by establishing a regional implementing body and centre of expertise to serve several small countries; through knowledge consolidation from institutions in different countries concerning regional climate and regional impacts. There is the possibility that these economies of scale may make a strong case to financiers to provide financial support.

4.3.6 Completing the Compendium of coping options

Table 1 presents a suite of coping options. Many of them have been practised for some time in countries such as Bangladesh, the Netherlands, various small islands, etc. In Table 4.1, wherever possible the coping options are linked to specific Dialogues. The summary descriptions of individual Dialogues in the yellow pages offer a little more information about the relevance of different adaptation actions in those specific situations.

The full reports of each dialogue are available for further amplification. Wide-ranging as they were, the dialogues could not be expected to encompass every possible option. To make the Compendium as comprehensive as possible, DWC has added coping options identified through the Thematic Papers and other literature sources. Hence, adaptation options based on amplifying solar radiation by chemicals (turning the snow black), ice-breaking, ice-cutting and blowing-up.

The Dialogue foresaw the need for a targeted and integrated science programme on water regime formation of the Yakutian rivers, on forecasting ice jam formation and on forecasting, preventing and remediating the consequences of floods. An application was to be made to the President of the Republic Sakha (Yakutia) to search for possibilities to finance this activity.

The Dialogue stressed the importance of defining problems from the point of view of national interest. This would align the prevention strategy towards reducing the nation's vulnerability. Recognising a need to raise wider public awareness and to disseminate the outcomes, the Dialogue participants sought to produce a popular video film and publications to feed the federal and local mass media.

Murray-Darling

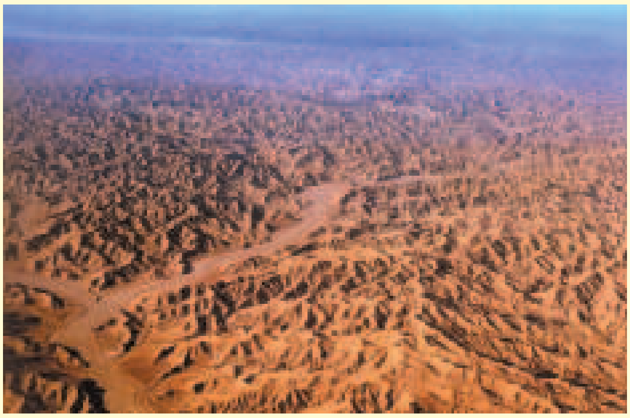
With an area of one million km^2, and a length of river of 3 780 km, the Murray-Darling basin itself is as large as some countries. Under natural conditions, there is very strong spatial and temporal variability of climate and precipitation. Nearly nine-tenths of the basin, lying in the arid and semi arid part, contributes no runoff to the system, except during floods. The basin is the powerhouse of Australian agricultural productivity, home to 70% of the nation's irrigation and contributing 40% of the national agricultural produce valued at AUS$10 billion. Clearly, there is already high water demand from the irrigated agriculture sector (including for high-value export crops). The basin is also a very significant contributor to the national tourism sector, filing some AUS$3.5 billion of revenues.

It is already a highly regulated river system, with present-day river outflows being just a quarter of what would be expected under natural conditions. Ecosystems and biodiversity are adversely affected by this regulation. As well as variability being already very high, there is concern that yet higher variability will lead to more frequent droughts and a probability of decreasing water availability. On top of problems already faced in salinisation and dropping groundwater levels, farmers and irrigators are most concerned about any further decrease in seasonal water allocations. Interestingly, one-off extreme events are not the greatest concern. Rather, it is the continuing breaching of critical thresholds, such as water allocation falling below 50% for more than five consecutive years (for irrigation) or water availability below breeding events for more than 10 consecutive years (for bird populations).

The Basin has already begun to adapt, but not driven primarily by climatic risk. Integrated catchment management and legislation are now implemented through the Murray-Darling Basin Commission, representing the five basin states and the federal government. The Commission is the regulatory body for water use and natural resource management. Recognising the importance of maintaining river flows for environmental purposes, a permanent cap has been placed on water abstractions since 1997 to maintain minimum flow conditions at a level that is environmentally appropriate. A suite of integrated water management tools are already in place for farmers and irrigators, such as SWAGMAN (Salt Water and Groundwater Management), RAINMAN (to forecast rainfall and river flow) and ENSO outlooks on forthcoming seasonal climates. These tools were not developed uniquely to address climate risks, but they have embodied those risks – and others – with them. The Basin has practised trading in water rights for more than two decades, as an economic tool to move water use to its highest value, maximising the economic benefit of the scarce resource. More recently, this has been expanded to allow interstate trading.

But a country as well-developed as Australia still sees potential for improving in its accommodation of climate risk. The participants in the Dialogue see scope for better forecasting and communication of probabilistic climate information. The value is seen in particular to be in risk-based operational management of seasonal water allocations. It would influence crop selection, irrigation investment, water trading and prices, dam operations and urban water design. There is acknowledged scope for the better management of environmental flows, based upon ecological benchmarks and the scientific assessment of ecosystem needs. There are also calls for the formulation of a nationwide drought management strategy. As a first step, a new integrated science initiative has recently started, partially as a result of the Dialogue. It will focus on adaptive irrigation management under global climate change scenarios, and on better understanding the long-term climate risk to water resources.

Yellow River



The Yellow River basin covers 800,000km^2, through which the river extends for 5,500km. It is located in the semi-arid, water scarce zone of northern China, characterized by high climate variability. The area is home to more than 110 million inhabitants – a figure that is rising - with densely populated flood plains. For centuries, the river has been a highly developed and regulated system.

Trends of decreasing precipitation have been detected. Abstractions of water have continued to rise, to a level at which they are now four times larger than the average river flow. Decreasing rainfall and increasing withdrawals mean that it is much more common that there is no flow at all in the lower reaches. This has transferred pressures of water use to groundwater, resulting in overexploitation and significant drops in the water table. Reductions in flowing water have degraded the ecology of the lakes of the upper reaches, of riparian such as artificial recharge and micro-insurance appear in the list without any cross-reference to specific dialogues, simply because they are options that will need to be considered in specific circumstances.

Table 4.1 distinguishes **mitigation** options from **adaptation** options. Within adaptation, the options are subdivided into:

- Policy Instruments
- Technological and Structural Measures
- Risk sharing and spreading
- Change of land use, activity or location.

Appropriate coping measures vary enormously, depending on the physical and socio-economic characteristics of a particular region and on local perceptions of vulnerability to climate variability. They are priority dependent, scale-dependent, and may vary from individual households to local communities to catchments, as well as from national to international scales. So, the Compendium is a menu rather than a checklist. Users (stakeholder dialogues for example) may typically find five or six options on the list that merit further investigation (early warning systems, reservoir operating rules, micro-credit, rainwater harvesting, adaptive spatial planning, awareness raising) for incorporating into a coping strategy.

Ultimately, actions to cope will be selected to overcome specific vulnerabilities, and to meet development objectives that are sectoral in character. It may well be that the over-riding sectoral interest in the North is the protection of the environment. Equally, the prevailing interests among developing countries may be economic and social development goals.

4.3.7 Mitigation matters

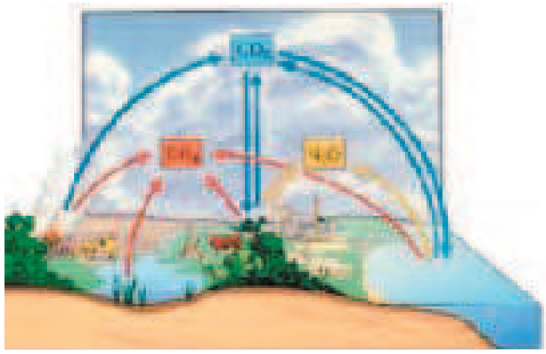
Mitigation did not feature prominently in the Dialogues, partly because of a prior orientation towards adaptation, and partly because mitigation actions lie outside the water sector, in energy, in industry and in high political decisions. However, mitigation actions remain a thrust of coping actions, and merit presentation in the broad portfolio

Reducing the sources of greenhouse gases

The action agenda of mitigation through emissions reduction lies mostly outside the water sector, and particularly in the energy and industrial sectors. There will be some implications for water managers, arising especially from the future energy mix. Water is a critical contributor to energy production, through large and small scale hydropower and through cooling of coal and gas-fired turbines. The choice of energy mix to achieve emissions reduction will have impacts in the water sector. Water managers will need to be aware of developments in this area, especially in relation to the Millennium Development target of providing energy services to the presently unserved. There may be a need to cope with the impacts of mitigation, and to determine whether water is at all a constraint to the ideal energy mix for emissions.

Enhancing the sinks of greenhouse gases

Biological mitigation can be achieved through three strategies; (a) conserving the existing carbon pools, (b) sequestration by increasing the size of carbon pools, and (c) substitution of sustainably-produced biological products such as wood for energy-intensive construction products and biomass for fossil fuels.



The largest biological potential for atmospheric carbon mitigation lies in subtropical and tropical regions. Realization of this potential depends upon land and water availability, as well as the rates of adoption of different land management practices. Some biological mitigation options may bring social, economic, and environmental benefits beyond reductions in atmospheric CO_2 – for example in watershed protection. On the other hand, if implemented inappropriately, they pose risks of loss of biodiversity, community disruption and ground-water pollution.

Water is used by plants to convert atmospheric CO_2 into terrestrial carbon. There is the risk that increased water use by plants will diminish river flows, and impact upon man's dependence on a water resource that is anyway diminishing from other factors. This poses the undesirable prospect of a 'double-whammy' – that local water resources already diminished by global climate change are further diminished by efforts to mitigate climate change.

4.4 Adaptation options explored

4.4.1 Policy aspects

Over the centuries, societies and ecosystems have adapted to climate variability and climate change in an evolutionary way. Today, the rapidity of changes in hydrological regimes requires more immediate and more concerted efforts. Policies and operating rules focused on optimum exploitation of available water resources need to be adjusted. The hydrological rules have changed. Put simply, continually updated assessments of meteorological and hydrological data need to be an integral part of water resources planning and management. That is rarely the case now. A fundamental aspect of any coping strategy therefore must be mainstreaming of climate issues into national water management policy.

vegetation along the course, and the delta and estuarine ecosystems. The river is further characterised by high loss erosion in the middle reaches, resulting in high sediment loads (1.6 billion tons/annum), and in concentrations that are increasingly high.

So, there is anyway a rising vulnerability to droughts and floods due to increasing population and water demand. This is compounded by the prospect that the witnessed rainfall trends are in fact a signal of increasing climate variability – tending further towards reduction of water availability and more extremes. Floods of equivalent size to those of previous years are exerting greater damage than before, and the silting-up of the channels causes river elevations to rise several metres above surrounding land. This is coinciding with a time in which Chinese governance is in transition, with the traditional strong centralised control structures continuing alongside newly emerging participatory approaches in water management.

Steps have already been taken to adapt, and like the Murray-Darling, these have not been driven primarily by climatic risk. A basin-wide allocation scheme was implemented in 1998 by the Yellow River Conservancy Commission. This was the first effort in China to integrate water resources management, river management and flood control at a river basin level. The allocation scheme includes priority setting for competing water uses (including hydropower). A new Chinese Water Law moved to the stage of implementation in October 2002. A new "Virtual Yellow River" project has been started, contributing to and used by all of the relevant agencies. It uses computer and satellite technologies in support of flood management, water allocation, water infrastructure projects, and is helping to strengthen the integrated management of the river. The river has been selected as one pilot basin of the Challenge Programme on Water and Food of the CGIAR, the Consultative Group on International Agricultural Research. This aims to produce more food with less water. But perhaps the adaptation of greatest significance lies outside the traditional water arena, in the WTO association of China. The effects of gaining access to world markets, of increasing food trade, of shifting from grain to livestock production will have very significant influence upon agricultural production, and so upon pressures upon water use.

Further steps are seen as necessary for the full course of adaptation to be pursued. Plans have been set in place for large-scale transfers of water from the South to the North. The new national water law will come into effect, adapted for the Yellow River, introducing coordinated legislation amongst the eleven riparian provinces. Improvements are sought in water use efficiency and in demand management, particularly in agriculture. Water pricing structures are needed that provide incentives and disincentives to control water demand effectively. But all plans are working with major uncertainties, since the current models predict very different outcomes for water resources. Rigorous planning will depend on more consistent scenarios of climate and water for the basin.

Nagoya

The Japanese city of Nagoya lies at the mouth of the Shonai River. The adjacent Kiso River Basin provides drinking water for more than 4 million people. On September 11 and 12, 2000, a total of 567mm of rain fell on the Greater Nagoya area, some 428mm of it in one 24 hour period. The previous record was 240mm in a day (in 1890). There were 9 deaths and 87 people injured. Damage totalled US$8 billion. This rainfall extreme comes alongside frequent droughts during the last decade in the Kiso Basin.

There is confidence that climate changes have already been detected. Observed temperature variations are consistent with the wider global evidence. Annual precipitation has shown a greater frequency of heavy rainfall events, yet also a reduction in overall rainfall amounts. It is acknowledged that these changes may be due to global warming and to long-term changes in atmospheric circulation - but they have not been established as the cause. It is recognized that they will, if confirmed, be responsible for greater flood and drought impacts in the community in the future. Lack of a full understanding has not been a barrier to action. There are already sufficient worries about the increase in flooding and the reduced availability of water in rivers, with concern also for impacts on ecosystems.

The wider significance to society has been recognised, kickstarting a process in which many viewpoints were engaged. An Exploratory Committee was appointed, with representation of the general public, administrative bodies and professional specialists. Their prime effort was to consolidate present knowledge and the problems faced, tapping domestic, national and international sources. Over 800 people participated in a national forum. Wide public awareness was achieved when the national forum was broadcast on the local NHK1 satellite TV channel. The efforts of the Exploratory Committee culminated in a set of four recommendations, calling for more intense observation of climate and the impacted water cycle, for better long-term forecasting capabilities in river basins, and for a risk management strategy that would alleviate damage through better public information. Finally, the Committee reaffirmed that continuing co-operation among stakeholders is critical to all their efforts. This foresees that better information sharing will lead to more reliable counter-measures, and the reality that the consent of many is needed if on-the-ground implementation is to be acheived. These recommendations underpin the future adaptation strategy of the Nagoya community.

The community has long protected itself against flood and drought. It has constructed levees, dams and bulkheads against

Enlightened stakeholders can help to stimulate climate-sensitive policy changes through advocacy, awareness raising and media campaigns, and by drawing national policy makers into their water-and-climate dialogues. Many of the adaptation options in the Compendium involve actions that both require and can influence an enabling policy environment. A few examples from many of this facilitating interplay between basin-level action and national policy setting are:

- the design of reservoirs and coastal infrastructure;
- water-related disaster management;
- land-use guidelines; and
- insurance systems to protect the poor against the effects of hydro-meteorological disasters.

In addition, supportive water policy can be encouraged from the top. The various Dialogues have highlighted a range of international, regional and national policy influences and these are listed under the "policy Instruments" heading in Table 4.1.

At the global level, the International Convention on Climate Change is influential in stimulating follow-up action at regional and national scales, so its principles and recommendations carry significant weight. The dialogues in West Africa and the Caribbean Islands both call for stronger representation in the processes of the Convention. The World Trade Organisation (WTO) negotiations have emerged as important in determining a nation's ability to cope (highlighted in the Bangladesh and Mediterranean Dialogues). It is higher level politics that will largely determine what happens in this arena, but with the implications for water-use changes implied by freer global food markets, water and climate issues need to be on the WTO agenda. Regional initiatives can bring economies of scale and often a high level of political will. Regional Adaptation Plans of Action are now being actively pursued in five of the eight Dialogue regions.

At national level, water-and-climate is a cross-cutting issue affecting many aspects of social and economic development. Poverty reduction and sustainable development are the two most obvious targets for mainstreaming climate issues, because of the threats to progress from extreme weather events.

Mainstreaming climate variability and change into water management policies

From an implementation perspective there are two broad kinds of interventions that facilitate mainstreaming. The first are interventions that reorient existing policies and practices in which climate variability is already integrated. Examples include the design of reservoirs and coastal infrastructure, water-related disaster management practices, land and water management systems, and, to a certain extent, national systems of innovation. The emphasis is on knowledge management and institutional strengthening to fine-tune policies and practices and make them more responsive to the enhanced vulnerability caused by increased climate variability and change.

The second group of interventions to mainstream climate change focuses on filling "policy gaps" to address current climate variability, while also enhancing the resilience of the water systems and the users (people and nature). Examples include climate or extreme event-related insurance of the assets of the poor against loss; appropriate pricing regimes for water and other natural resources to ensure their sustainable access to the poor; and land-use planning that avoids marginalizing the poor, forcing them to live on flood plains, or in coastal storm surge areas or land slide-prone slopes. These 'no-regrets' interventions focus on removing barriers to the adoption of policies that are sensitive to the impact of

Box 4.1 Using water markets in the Murray Darling Basin, Australia

Water trading, or the buying and selling of water, has been occurring in the Murray-Darling Basin for almost two decades. In an area which has frequent droughts, and were there is intense competition for water, trading helps make the distribution of water more efficient. Initially, trading was confined to trades within irrigation systems. Over time, changes have been made to the trading rules, which have permitted inter-valley and more recently interstate trade to take place. In recent years, state governments have been working together to reduce the differences in water entitlements in preparation for the introduction of increased interstate water trading. A Pilot Interstate Water Trading Project was set up in 1998. This has facilitated the interstate permanent trade of high security water entitlements between the States of New South Wales, Victoria and South Australia in the pilot zone which lies between Nyah on the mid reaches of the main stem of the River Murray and the Murray mouth in South Australia. The Pilot Project is providing very valuable information which is expected to pave the way for opening the interstate trade further up the River Murray and ultimately to the entire Basin.

The objectives of the Pilot project are:

- to facilitate and promote the interstate transfer of water entitlements co-ordinated by the Commission;
- to improve the efficiency and effectiveness of consumptive water use in ways that facilitate environmental sustainability, but which do not increase or accelerate environmental degradation;
- and to establish a procedural framework and a set of standards to demonstrate that water trading is accountable and does not result in increased levels of salinity, reductions in environmental flows, or degradation of the natural environment.

too much water, and reservoirs against too little. These structures protect the community against the 1 in 100 year flood and the 1 in 10 year drought. Concerned at the low level of protection against more extreme events, new coping measures have been proposed. Against floods, there is a demand for better awareness of the measures already in place, and that those scheduled previously are completed. There are calls for strengthened structural measures (levees and flood control throughout the basin), for improved non-structural measures (improved planning in urban areas, refuges and flood hazard mapping), for better real-time reservoir operation to mitigate abnormal floods, and for improved measures to get information to the general public.

Against drought, improvements are sought in the operation and management of facilities. These include optimizing the existing storage installations as a more integrated system, and introducing more flexibility into the reservoir operating rules to maximise availability. Scope is seen for reducing water use through saving and re-use. Rainwater harvesting schemes, already successfully operated at the Kokugikan and Korakuan stadiums, are seen as having a much wider potential.

Small Valleys

The Central America Small Valley Flood Alert and Vulnerability Reduction in Central America Programme (SVP) develops low-technology early warning systems for floods. These early warning systems are managed directly by the local communities. The SVP is co-ordinated by the Organisation of American States in consultation with the Regional Committee for Hydrological Resources in the Central American Isthmus (CRRH) and the Central America Center for Prevention of Natural Disasters (CEPREDENAC). The future activities of this programme, coordinated through the Dialogue on Water and Climate, will bring existing community-based SVP groups together in a concerted effort to support the management of floodplains in small valleys.

This is to be achieved through a new regional platform for training and technical advisory services. Specifically, the programme will support local communities in developing and implementing early flood alert systems. Support will be given in organisation and training in flood emergency management. This has the purpose of reducing the vulnerability of the local economic and social infrastructure. The programme, which started as a pilot study in a coastal watershed in Honduras in 1995, has expanded to include small flood-prone valleys in Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, and Panama.

The SVP programme is based on the use of simple and inexpensive instrumentation. This includes rain gauges made from PVC or soft drink bottles, and measuring-tape gauges of river levels. Since electricity does not reach into many of the rural areas, communication is by battery-powered radio. Upstream, the rain and river level gauges are located along the basin (perhaps 5 to 10 in number, depending on the size of the catchment), each with a volunteer in charge of recording and communicating the data. Downstream, there is another small group of volunteers, perhaps three or four, who receive data from the volunteer observers upstream. They use the rain and river-level information together with a pre-prepared chart to predict the occurrence of a flood. This prediction is then communicated to the local authority who decide whether or not to issue a warning. When a warning is called, the different local emergency committees, mostly volunteers, implement their emergency plans.

By far the biggest challenge has been found to lie in training participants on how to build and maintain the instruments, how to interpret the data, and how to communicate the findings. A second challenge has been in securing the "buy-in" – obtaining community interest and support. This includes educating the community about the value added by such a programme, and providing incentives to upstream participants to monitor and communicate data and information to those downstream. Third, there is much to be done in fostering community preparedness for flood emergency planning and response. Fourthly, it is necessary to encourage vulnerability reduction, gaining penetration into the planning and implementation of the social and economic infrastructure.

In order to address these challenges, the regional platform of the SVP has determined that a coordinating mechanism is now needed. Such a mechanism will be responsible for training, outreach, follow-up, maintenance and (when necessary) outreach to national governments and donors. Regional leaders of the SVP programme have already undertaken the process of identifying a regional NGO that has the will and knowledge to undertake this task. They are in the process of seeking the required funding.

National Dialogues

Bangladesh

Bangladesh is one of the poorest and most densely populated countries in the world. The poor are particularly dependent upon safe and reliable water for improvements to their health and livelihoods. There are complex interactions involving monsoon rainfall, river flow fluctuations, groundwater availability, saline intrusion, fish availability and many other factors to do with daily lives of the populace. Poor rural and urban communities in all parts of Bangladesh are affected severely by climate variability.

Damage from floods and storm surges has been particularly extreme in the last 15 years, with 1992 and 1998 being the climate variability and change on water management and water availability. Activities to support these interventions could include knowledge management, institutional strengthening, and vulnerability assessments to prioritise adaptation interventions. In all cases, policy oriented actions should go together with informed awareness raising activities for the public.

Integrated water resources management (IWRM) is widely recognised as the most effective way to optimise water availability for all uses, though the institutional strengthening it demands poses challenges to many developing countries. With IWRM and its extension to integrated catchment management comes an increased flexibility to cope with large fluctuations in rainfall and river flows. IWRM also facilitates the use of risk management techniques and "water markets" (see Box 4.1) to moderate the impacts of seasonal and interannual variations in climate.

4.4.2 Implementation challenges and opportunities

It is often noted that even when policies are in place, they are not implemented because one or more of the parties responsible for implementation fails to follow through. In the most vulnerable countries, institutional frameworks are lacking and preparation insufficient – or simply unaffordable to government amidst many pressing priorities. Adaptive capacity is a prime element of vulnerability, and an area where there is an urgent need for capacity building.

Organisational, policy and legal improvements have been instituted worldwide since the Earth Summit in Rio de Janeiro in 1992, but few countries have developed the comprehensive national water management policies that were agreed to by Heads of Delegations in Rio. If the political agreements of The Hague and Johannesburg are carried through, this will be pursued with vigour in the immediate future. The door is open for coping policies to become embedded in national water policy. So, the policy objectives of coping with climate need to be clear, and they need to be ready.

The Millennium Development Goals, supplemented by the World Summit on Sustainable Development (WSSD) Implementation Plan, have brought the provision of affordable water supply and sanitation services to the top of the development agenda. To halve the proportion of each country's population lacking basic services by the target year 2015 will mean an extra 1.6 billion people gaining access to a safe water supply and 2.2 billion obtaining improved sanitation facilities in 15 years. That translates to improving sanitation services for about 400,000 people every day. It is a formidable challenge, but not an impossible one. It is though put at considerable risk by the threat of storms and floods destroying flimsy infrastructure or droughts leaving hand pumps high and dry.

It follows that strategies to cope with climate extremes and those to meet water and sanitation targets are mutually reinforcing. Water planners and managers will bolster their chances of meeting the sanitation targets if they build resilience to climate into their technology choices.

A linked issue is the use of global adaptation funds. If adaptation funds are limited to existing water management systems alone, then they increase the marginalisation of the poor. The water services industry has traditionally invested more in the upgrading of the services for those already served than in providing basic services to the unserved. Adapting water management to climate change could lead to the same skewed priorities. There is a powerful ethical argument that adaptation funds should be made available for investment in basic services for the unserved designed to reduce vulnerability to climate-related disasters (see Chapter 5).

4.4.3 Structural and technological options

The list of coping options under this heading in Table 4.1 will seem to many readers like a catalogue of water management infrastructure and operating techniques. It is true that coping with climate does not involve any innovative new processes. What it does mean is reviewing existing operations in the light of very different hydrological circumstances.

Basin infrastructure is essential to protect against and reduce the impact of water-related disasters. As well as new civil works like disaster shelters in risk-prone areas, it can be very practical to improve existing infrastructure such as roads, drains, natural ponds and lakes, dams, reservoirs, soil conservation of steep slopes and sediment control into reservoirs. Proper skills for operation and maintenance and the financial means to carry them out are equally important.

Box 4.2 The impact of storage degradation in Kenya

The World Bank has estimated that the 1997/98 El Niño floods and the 1999-2000 La Niña drought cost 40-49% of Kenya's GDP and that water resource degradation costs the economy about 0.4% of GDP every year (World Bank, 2002). Investment in water resources infrastructure in Kenya has been very low. Only 15% of the safe yield of renewable water resources has yet been developed. Because of increasing population and degradation of reservoir storage, the water storage per capita has declined from 11.4m^3 in 1969 to about 4.3m^3 in 1999. Current water sector reforms have the potential to reduce degradation costs substantially through better management and investment in badly needed infrastructure. Increased water storage combined with early warning of El Niño/La Niña is seen as an important way of reducing costs of future floods and droughts.

worst in living memory. Floods have proved the most costly natural disaster in terms of human suffering and economic losses in the country. One fifth of the country experiences regular flooding each year and all the previous major floods have inundated more than fifty percent of the country's total area. Conversely, low rainfall years (such as 1997 and 2001) have also had serious implications for agricultural productivity, fish availability and other aspects of rural livelihoods. Surveys conducted in villages and rural areas show that Bangladeshis are convinced their climate is changing. They may not understand why this is so, but they are certainly interested in learning how best to cope.

Given its history of recurring flooding, it is not surprising that Bangladesh has many sectoral policies to reduce climate-related impacts. The recent National Water Policy emphasises flood, drought and salinity management. A disaster management policy - the "Standing orders on Disaster" - provides guidelines for disaster mitigation with an obvious focus on cyclone and flood management. The national environmental and agricultural policies also provide guidelines on floods from the perspectives of land-use and water quality. However, there is no specific national policy for addressing climate change.

In term of addressing deficiencies in the existing policy guidelines, the Dialogue participants identified the need to move away from the more traditional solo approach of sectors to a more holistic approach of oversight. They saw a need to give more consideration to climate change in decision-making – especially in its effects upon water. They further saw a need to foster a coordinated effort that would build their national capacity to cope.

It is well recognized that achieving these needs will take considerable time. Pragmatically, they highlighted an urgent need for immediate action, recommending three steps forward where rapid progress could be made. The first is that climate variability and change be accommodated within the National Water Management Plan that is currently under preparation. It is acknowledged that the current draft version of the strategy recognises the "knowledge gap" on the potential impacts of climate change. It is further acknowledged that this gap presents a major challenge to finalising the Plan. But while the knowledge gap can not be overcome imminently, it should not present a barrier to planning for adaptation in the face of uncertainty. Second, coping mechanisms that are specifically related to water must be included in the country's National Adaptation Plan of Action (NAPA). Finally, improved co-operation with upstream countries is seen as essential to flood prevention and preparedness, but early breakthroughs are acknowledged to be extremely difficult under prevailing geopolitical conditions.

The Netherlands

The Netherlands is a small country in a unique position. Much of the country lies in a delta, and below sea level. Population density and economic investments are both very high, and a sophisticated water management system has developed. It is natural, that the climate extremes most feared are those that increase floods - whether from the sea (due to high sea levels), from rivers (due to peak flows) or from extreme local rainfall and inundation. So, floods have been centre of attention, but other anticipated impacts are beginning to enter the frame.

Institutionally, management of the nation's water systems is well integrated at all levels of government. But despite its high level of development, and despite the severity of risk posed, the Netherlands - like many countries with considerably less

resources – has struggled to translate projections of climate change into medium and long-term policy plans. To do so requires that the government strike a balance between short-term economic growth and long-term sustainable development. Implementation of policy has posed an even greater challenge. The level of scientific knowledge and technical skills are among the best in the world. But there remains a low level of penetration of the issues into the wider public perception and the political debate. A series of incidents in the 1990s of very heavy rainfall and high water levels in the rivers Rhine and Meuse proved an important catalyst to action.

The main water impacts of climate change have long been identified as flooding and drainage, drought and water shortage, and water quality and salinisation. There is little new there to discuss. So the Dutch Dialogue explored the more indirect impacts to which water is relevant. These were agriculture and food production, environmental affects due to and during floods, hindrance of navigation, temperature effects on eutrophication, and efficiency of cooling water systems.

The way forward to-date has been in line with international conventions. Pursuant to the IPCC framework, the Dutch government formulated "The Netherlands' Climate Policy Implementation Plan (Parts 1&2, 1999)". The Plan focused uniquely on mitigation and no national adaptation policy has yet been formulated. Dutch water managers now see a paradox. On one hand, there are many policy reports that state that the climate is changing, that it will continue to change in coming decades, and that it must be dealt with. This brings adaptation to the forefront. On the other hand, the official standpoint is that the Netherlands government will do everything possible, at home and in the international arena, to mitigate the change. This suggests that change can be contained and that adaptation does not constitute a priority.

Though a national adaptation policy has not been formulated, Dutch water management organisations have highlighted the need to focus efforts at the regional climate scale rather than the national. It was realized also that a most important aspect would be the changing variability. Aware that extreme events are more uncertain and difficult to predict, it was evident that planning would have to accommodate increasing uncertainty. Further, it was evident that closer co-operation was needed between water managers and climate researchers.

Dialogue participants were unanimous in agreeing the greatest obstacle to the implementation of adaptation measures. The chief culprit is to be found in the lack of institutional co-operation, allied to a lack of awareness amongst politicians and the general public. So, although there is wide support for water management that is more resilient and sustainable, implementation is anticipated to be slow and uncertain. This would be helped by better integration of the water management sectors, bringing more transparency, stakeholder participation and use of proper instruments.

Storage:

Reservoirs are a robust, resilient and reliable way to manage water under a variety of conditions and uncertainties. Increased storage is a logical option to cope with changing hydrological parameters (rainfall and runoff). Unless storage and operating rules keep pace with growing demands and varying hydrology, the impacts of drought and/or floods can be exacerbated (see Box 4.1). New dams and reservoirs are not always a popular solution though. They raise controversies over environmental and resettlement issues and have been blamed for spreading vector-borne diseases like schistosomiasis and malaria. In December 2000, the World Commission on Dams produced a comprehensive report *Dams and Development: A New framework for Decision-Making*, promoting five "core values" – equity, sustainability, efficiency, participatory decision-making, and accountability. The framework and guidelines are to guide projects for new construction and for rehabilitation of dams. The guidelines do not include climate considerations yet.

Surface water storage is subject to evaporation losses that depend on reservoir geometry (smaller and shallower reservoirs have higher losses) and climate (annual evaporation rates can exceed 4000mm in dry, hot regions). Evaporation can be expected to increase with global warming. Boosting groundwater storage through aquifer recharge can have advantages over surface water storage, because of the reduction in evaporation losses. By way of example, if 50% of the surface water storage for the supply of Windhoek, Namibia was transferred to underground storage, the decrease in evaporative losses would equal about 60% of the water demand of Windhoek. A study on groundwater storage potential in relation to climate change was started under the DWC. The study concludes that the potential for groundwater storage is limited because of geological and hydrogeological conditions, but nevertheless there is scope to make considerably more use of it than at present.

Water for aquifer recharge may be diverted urban stormwater runoff, irrigation return flows or, with appropriate controls, reused municipal wastewater. At local level, rainwater harvesting is growing in popularity as a cost-effective way for the unserved poor to obtain improved water supplies. It has the additional benefit that it adds to the resilience of community water supplies at times of extreme weather events.

Existing surface and groundwater storage schemes may well be negatively affected by climate change. In China, for example, the cost of maintaining current water supply from reservoirs under climate change conditions predicted by three GCM Scenarios is estimated to be US$28 billion. This is despite the fact that in China's three most water-scarce regions, reservoir yields actually increase under the same GCM Scenarios.

Flood/Storm Surge Control

For cities and coastal regions susceptible to floods and/or storm surges, each disastrous event brings a further review of control structures. River bed deepening and widening, diversion channels and extra flood basins are among the protection measures that need to be reviewed in the light of increasing risks of extreme events. Raising flood embankments is a common, if expensive solution. It can also be a risky one, as future overtopping and failure of raised flood defences will add to the perils of those "protected" by them.

Disaster shelters constructed in Bangladesh after the 1991 cyclone killed 140,000 are considered to have been very effective in saving lives during later storm surges.

Early warning systems

Early warning is the provision of timely and effective information, through identified institutions that allows individuals at risk of a disaster, to take action to avoid or reduce their risk and prepare for effective response. Systems may provide short-term (2-5 days) weather forecasts for well-defined local areas, or medium-term (seasonal or inter-annual) forecasts predicting whether rainfall and temperatures will be above or below average in particular regions,

Short term

Early warning systems based on short-term local weather forecasts and up-to-date hydrological information are enhancing operations and disaster preparedness, particularly in relation to floods, storm surges and cyclones. They require a high level of local participation and a strong network for data gathering and dissemination. The *Flood Vulnerability Reduction and Development of Local Warning Systems* programme in Central America, featured in the Small Valleys Dialogue, shows that such systems can be relatively cost efficient. Another example is the advanced early warning system operational in Bangladesh (see section 1.4.3), which expresses hydrological data about impending floods in ways that can help to determine basin-wide impacts. There are also flood early warning systems in Europe, and a community-operated early warning system in Guatemala.

Medium term

Medium term prediction systems are especially relevant for agriculture. Regional and local seasonal predictions are being developed and linked to agricultural extension in for example Brazil, southern Africa and the Indonesian archipelago.

Weather forecasting tools are getting better, covering longer and shorter time horizons and larger and more local spatial scales. At regional level and for long time scales, climatologists are now able to produce weather forecasts of modest accuracy particularly for the tropics,

Regional Dialogues

Aral Sea

The case of the Aral Sea is one of the greatest environmental catastrophes ever recorded. People have made use of the waters of the Aral basin for thousands of years, taking from its two major rivers: the Amu Darya, which flows into the Aral Sea from the south; and the Syr Darya, which reaches the sea at its north end. Since the 1960s, agricultural demands have deprived this large Central Asian salt lake of enough water to sustain itself, and it has shrunk rapidly. Uzbekistan, Kazakhstan, and other Central Asian states use the water to grow cotton and other export crops, in the face of widespread environmental consequences of fisheries loss, water and soil contamination, and dangerous levels of polluted airborne sediments. It is generally agreed that the current situation is unsustainable, but poverty and export dependency of the Central Asian states have prevented real action, and the sea continues to shrink.

Based on several modelling studies presented to the Dialogue, climate change is expected to have a number of impacts on the Aral Sea basin. Glaciers are shrinking, although at present there is not enough evidence to suggest whether this is occurring due to climate change or natural climatic cycles. Inflow to the Aral Sea from the Amu Darya and Syr Darya is expected to decrease by 20-24% by 2020, depending upon the development scenario. Due to aridisation and increases in precipitation, the contribution of runoff due to snow melt is expected to be reduced by 5-10%. Agricultural yields of some crops - cotton, alfalfa and maize - are expected to increase, but decreases in rice yield are expected due to temperature increases. Results of calculations from the Aral Sea Basin Management Model indicate that climate change is expected to have a positive effect on food security, with a 5-7% increase of available calories production per capita.

The Dialogue identified a set of five actions, or directions for needed actions. The Aral Sea Basin Management Model needs to be implemented to demonstrate the regional sustainable development possibilities in water resource management and co-operation in food production under the influence of climatic changes. An assessment of the influence of climate changes on water resources available in the Aral Sea basin is recommended. Possible means of rational water use in irrigated agriculture in the Aral Sea basin were to be investigated with regard for climate changes. Calls were made for a strengthening of the region's interstate co-operation to implement its policies in water saving and nature protection. Calls were made also for an appropriate legal and financial mechanism that would lead to strict and effective water use and water sharing.

South-east Asia

The South-east Asia Dialogue covered Cambodia, Laos and Vietnam. These countries are particularly vulnerable to weather-related natural disasters due to their lengthy coastlines along the Western Pacific Ocean. Flooding from heavy storms, torrential rains and typhoons causes the worst damage. In the past four years, weather conditions brought flooding of historic levels to many parts of the region. According to studies funded by the Asian Development Bank and conducted by Vietnam's Hydro-meteorological Service, projections of the impacts of climate change include:

- increase in frequency and intensity of typhoons;

- a change in timing of dry season and rainy season;

- more droughts; and

- more floods, particularly late ones.

Despite efforts to improve early warning systems and emergency assistance procedures, hundreds of people are killed each year. The goals of the Dialogue were to analyse the resilience of wetlands and water resources to climate change and identify hot spots of vulnerability and to identify and evaluate climate change adaptation options and the main barriers to implementation.

Vietnam is one of the most typhoon-lashed nations in Asia. Every year, an average of four sea-borne typhoons and many more storms wreak havoc on this low-lying country. Planting mangroves is helping to protect the coastline from current extreme events and future climate change. Since 1994, the Vietnamese Red Cross has planted 12,000 hectares of mangroves, at a cost of US$1.1 million. The benefits are enormous for the coastal zone ecosystems, economy and people: the project has helped reduce the cost of dyke maintance by over US$7 million per year. Lives, possessions and properties have been saved from floods. And the livelihoods of an estimated 7,750 families have benefited by selling the crabs, shrimp and molluscs that mangrove forests harbour.

Box 4.3 The 1993 and 1998 droughts in Ceará, Brazil

In 1992, rainfall in the state of Ceará was low, water supply levels for the city of Fortaleza were low, and the city was suffering from a cholera epidemic. A forecast of 'normal' precipitation for 1993 led to a 'do-nothing' response from water managers. As it turned out, the drought of 1993 was among the worst of the 20th century and river flows were very low throughout that year. At the time that the forecast for 1998 (below-average precipitation) was issued, the water levels were low but not critically so. A technical committee comprising forecasters, water managers and the Secretariat of Water Resources briefed the Governor. A decision was made to invest in repairs of the Trabalhador´s canal, built in the 1993 drought to transport water to Fortaleza. A widespread drought came to northeast Brazil, but Fortaleza was not subjected to the water shortages suffered by many big cities in the region.

though there remain substantial uncertainties in climate projections, particularly for the higher and lower latitudes. The 1997/98 El Nino events were the first to be detected and made known through alerts to a network of organisations in many regions of the world and this led to significant savings in lives and property. There were other gains too. The Peruvian Ocean Institute protected seas from over-fishing in 1997 and, in consequence, marine biota returned to normal population levels in the third year after the event.

Many initiatives are under way to create or improve medium-term warning systems, a *Famine Early Warning System Network* (FEWSNET) in Sub-Saharan Africa is one example.

Some key questions need to be addressed when considering introduction of an early-warning system:

Box 4.4 Rainfall forecasting – A Case Study from Fiji Islands.

Rainfall in Fiji is highly variable with distinct wet and dry seasons which can have serious impacts on the nationally important sugar industry. This variability is closely related to the El Niño Southern Oscillation (ENSO), as was demonstrated by the severe drought impacts on sugarcane resulting from the 1997-98 El Niño. The Fiji Meteorological Service (FMS) has in recent years made significant progress in developing a seasonal rainfall forecasting scheme based on the Southern Oscillation Index (SOI) and has been promoting the application of forecasts in a number of sectors. A recent study carried out by FMS in partnership with the Fiji Sugar Corporation and the University of the South Pacific has produced a management strategy for the sugar industry using the rainfall forecast. This example of a seasonal rainfall prediction scheme has generated interest in the possibility of adapting the method to other Pacific Island countries.

- the purpose (target group)
- Is there a framework for institutional cooperation, and who ultimately is to respond to the forecasts?
- Are there specific trigger points at which contingency plans are put into action?
- What is to be forecast – the specific parameters of an event (if so, which), or the general (non-)occurrence of an event?
- The accuracy of the forecast - how has past performance compared with what was later observed? (see Box 4.3)
- The lead time of the forecast - how far ahead can the forecast be made?

Although long-term climate scenarios cannot meet the operational needs of today's water managers, short and medium-term weather and climate forecasts can be of huge benefit. Further improvement in short-term forecasting (3, 15, 30 and 90-days) is seen as one of the more important technological breakthroughs that will improve adaptive capacity. However, these forecasts are not yet being used in many parts of the world in water management, partly for lack of capacity, but also because the potential has not yet been realised by water managers.

4.4.4 Sharing and spreading of risk

In any one year, the number of individuals affected by climate-related impacts is significant in itself, but actually constitutes a very small proportion of the total population. Disaster insurance is a classic means for dividing risks and losses among a higher number of people over a long-time period.

Payouts on natural disasters are potentially massive, and very much higher than any single small or medium-sized insurance company could bear. For this reason, there is an active market in re-insurance. Individual insurance companies sell on much of their risk to re-insurance companies who carry large and complex portfolios. Re-insurance companies operate on the basis that it is improbable that there will be a 'run' of major disasters within a short time - in infrastructure, shipping or loss of life.

The cost of premiums can be very high for major infrastructure, and many governments do not take out insurance cover, choosing instead to bear the replacements cost of the partial losses that inevitably occur from their capital budgets. Provided long-run costs of replacement remain less than the cost of premiums, this is a sensible approach – for societies, this approach relies on Government investment into replacement. A major problem arises when a disaster is of such magnitude that it overwhelms the capacity of an economy to bear the cost from the national recurrent budget.

Recognising that climate-related hazards are not only inevitable, but are likely to continue increasing, insurance mechanisms are seen to have a role in

Central America

During the Earth Summit in Rio de Janeiro in 1992, the Presidents of Brazil and the Central American countries signed the regional Central American Climate Change Convention (CCC). At the same time, recognising the scientific complexity of the issue and the strong political implications that the climate change would have, they requested that their Foreign Affairs Ministers prepare a regional treaty that was to include a scientific and political follow up mechanism to support future regional decisions. The Central American Commission on Environment and Development (CCAD) and the Regional Committee on Hydraulic Resources (CRRH) were asked to take the lead and to support the actions of the UNFCCC and IPCC. Since then, CCAD has been active in the regional political process, concerning itself mainly with the mitigation of emissions of greenhouse gases and emission tradings. In tandem, CRRH has been active in the sphere of impact assessments and adaptation options. Several regional vulnerability assessments have been produced in the areas of agriculture, water resources, sea level rise, forestry and human health. However, adaptation strategies have received little attention.

Events surrounding Hurricane Mitch in 2001 re-ignited interest among stakeholders and decision-makers, leading them to revisit the hazard preparedness and disaster management plans of the region. It stimulated the desire to find the means to reduce vulnerability and to adapt better to current climate variability and long-term climate change.

Participants at the Central American Dialogue reiterated the importance of formulating and adopting adaptation strategies. They developed a Framework for Adaptation, setting out a detailed and comprehensive catalogue of specific adaptation strategies. These include technical, socio-political, and economic adaptation in the areas of domestic water use, irrigation, industry, hydro-electrical power, navigation, water quality and the management of floods and droughts.

A second important issue arising from the Dialogue was that of education at all levels, but with a particular emphasis on youth. The region has several innovative youth education programmes, and not confined only to schools. For example, CRRH has launched a programme to provide computers to Scouts groups, teaching them how to access information about water and climate.

To move the Framework for Adaptation forward, partners are presently in the process of setting up a series of small projects in which the Framework can be applied. The regional dialogue is anticipated to continue and to grow, reaching out to broader sectors. Having proven successful thus far, the efforts in education are certain to grow as far as available finances will allow.

Caribbean Islands

For most Caribbean islands, rainfall is the main source of freshwater, yielding direct rain, surface and groundwater. Rainfall differs significantly, with parts of Dominica receiving the most (7700mm per year) and Antigua and Barbuda the least (1000mm per year). As exceptions, the Bahamas and Antigua and Barbuda rely mainly on desalination plants for their water needs. Vulnerability has become associated with Caribbean Small Island Developing States (SIDS) because the countries tend to be very exposed to factors outside their control. Economic vulnerability exposes the economies to shocks to the systems of production, distribution (especially markets), and consumption. Environmental vulnerability is high, with risk of damage to the country's fragile ecosystems. Social vulnerability is also high, with small societies and socio-economic groups affected negatively by stresses and hazards. The islands are especially vulnerable to changing conditions of climate.

In response, the ACCC project – Adapting to Climate Change in the Caribbean – has emerged from the desire of Caribbean Governments to sustain successes from earlier projects. A feature of the institutional arrangements for the ACCC is a decision by CARICOM Governments to establish a Caribbean Community Climate Change Centre. This Centre, established in 2002, will execute the ACCC and serve as a Centre of Excellence. Self-funded, revenue streams are foreseen from a Trust Fund supported by international foundations and private sector contributions, the proposed Climate Change Adaptation Fund, and fees for certification services under the Clean Development Mechanism (CDM). Some key objectives of the ACCC are to ensure that countries build climate change adaptation into planning and assessment processes in all key economic and social sectors, to support effective participation in international negotiations and to ensure that citizens, private sector and governments of the region have the necessary knowledge and information for appropriate responses at home and internationally. The $(Canadian) 2.9 million project consists of nine components, including adaptation in the sectors of human health, water, and agriculture and food. Cross-cutting areas are in targeting planning processes, public outreach, technical capacity, environmental assessments, fostering collaboration, and the Climate Centre.

Caribbean countries will develop a more methodical and systematic identification of health impacts, thereby ensuring sharing and spreading risks. The World Bank plays a major role in backing national economic interests, and there are other very significant players, such as Munich Re and Swiss Re – two of the largest re-insurance companies. The principles of insurance apply across a whole range of circumstances, from the national to organization and to the household. In the US, 50% of private property loss is paid by insurance, whereas this is less than 1% in developing countries. In the insurance world, the interest in insuring against floods and extreme events is increasing. Recently, the Dutch government decided that flood damage should be made insurable. New insurance products and mechanisms are consistently under development by the insurance industry. Crop insurance and microinsurance mechanisms are providing risk transfer to individual (often poor) farmers and other groups who lack access to traditional formal insurance and finance.

Both Morocco and Cambodia are investigating and piloting a risk management approach to alleviate loss of agricultural income due to natural hazards. The Government of South Africa is in the process of debating legislation to stimulate a market in crop insurance. Despite the seemingly insurmountable odds against government-run multi-peril crop insurance programmes for the small scale, traditional or subsistence farmers, there is a growing number of specialists who believe that a modified crop insurance scheme for small farmers can be developed and implemented in a viable and sustainable manner. New partnerships in disaster preparedness are developing between governments and insurance companies that introduce stronger market mechanisms. These are currently mostly limited to developed countries (e.g. US National Flood Insurance Programme).

Sharing and spreading of risk is not confined to insurance. Alternative risk transfer tools, such as catastrophe bonds, are making available additional capital from international markets and thus providing for further risk spreading. Again, these tools are mostly limited to developed countries. Development banks are providing incentives to behavioural change through their lending policies. At household level, microfinance enables families and groups to rebuild economic activities and livelihoods after disasters and to help themselves out of poverty. For example, in Bangladesh, Grameen Bank lends US$30 million a month to 1.8 million borrowers, BRAC provides loans of between 1000 thakas (US$20) and Tk 20,000 (US$400). Governments provide several types of support for disaster response, with workfare programmes successfully maintaining livelihoods for affected people (e.g. Frente de Trabalho in North-Eastern Brazil), providing employment in periods of drought.

When a disaster occurs, immediate assistance is required in water, food, shelter and medical care. The International Federation of Red Cross and Red Crescent Societies (IFRC/RC) Disaster Relief Emergency Fund provides un-earmarked resources to allow for start-up operations within 24 hours. Substantial bilateral humanitarian and emergency response funds are usually mobilized at the request of affected States. As well as direct assistance during inundation, it is important to start post-disaster aid as early as possible. During and after the catastrophic Mozambique flood of 2000, it became clear that, as well as food and medicine, clean water was a critical issue. Unfortunately, because the flood did not hit the international headlines until it was well under way, international aid started late (except that from the Republic of South Africa). As a result, malnutrition and water-related diseases caused a higher death toll than the flooding itself.

Most calls for post-disaster response to be converted to pre-disaster investment are targeted at the bilaterals and, to a lesser extent at relief agencies such as IFRC/RC. While the economic and social logic is there, the argument is not yet won, and there is work yet to be done on both sides. Bilateral support is at the request of recipient governments, and so pre-event investment relies upon it being a national priority, integrated into national development plans, and particularly into poverty reduction strategies. Emergency-response funds are rarely pre-budgeted, and are drawn down on political decisions when requests for assistance are issued to the international community. Funds for strategic investments and response funds are often drawn from separate departments, and often different agencies, each with their own mandate – either to invest strategically, or to respond. The case argues for some portion of funds to be transferred from the response agency to the strategic agency – but for the response agency, any such funds are rarely pre-assigned. Very strong influence will need to be brought to bear if a sea-change is to be achieved. This issue is discussed in more detail in Chapter 5.

Not all forms of risk-spreading involve money. Farmers have traditionally dealt with risk by spreading their resources. They have always taken steps to build-in their own insurance through their cropping and planting strategies, careful that one failure will not prove to be a catastrophe. It is an approach that can be developed and enhanced by better forecasting and co-operative action with support for alternative crops and planting schedules.

4.4.5 Change of use/activity/location

Sea level rise, shrinking natural lakes and desertification all force changes of land-use and livelihoods. The increasing susceptibility of flood plains to extreme events means that governments have to consider prescriptive spatial planning as a coping option. Resettlement is neither popular nor desirable, but it may eventually become inevitable. In the Dialogues it became clear that, even in the bottom-up strategic planning, switching livelihood practices could not be excluded.

appropriate interventions. The Caribbean Epidemiology Centre has begun to determine whether a relationship exists between climate variability and climate change and the incidence of Dengue fever. In agriculture, measures are proposed that will assist farming communities, through agricultural departments, in identifying crops and agricultural practices best suited to climate change-induced conditions. Early steps will strengthen the capacity of Ministries of Agriculture and Forestry in the preparation of Action Plans. Against the hazards of sea-level rise, use will be made of the guidelines for Comprehensive Hazard and Risk Management (CHARM), developed by the South Pacific Applied Geosciences Commission (SOPAC). Support with the implementation of some of the actions should be forthcoming through the ongoing project on Mainstreaming Adaptation (MACC) and the Integrated Watershed and Coastal Area Management Project (IWCAM).

The feasibility of establishing an insurance pool among Member States in the Alliance of Small Island States is an area for further exploration, as first mooted in 1991 by Vanuatu. This insurance pool, drawing its revenue from mandatory contributions from developed countries, was to alleviate the financial burden of loss and damage suffered by the most vulnerable small islands and low-lying developing countries. No insurance-related mechanism has so far been implemented under the UNFCCC or the Kyoto Protocol, but a March 2000 workshop urged that insurance-related actions be explored further.

Pacific Islands

Participants at the Pacific Dialogue included 18 Pacific Island Countries (PICs), together with East Timor and the Maldives. The 18 PICs cover only 550,00 km^2 of land, with roughly 7 million inhabitants spread across 180 million km^2 of ocean. Excluding Papua New Guinea – a non-qualifier as a small island country but containing many small islands – these figures drop dramatically; the land mass amounts to only 88,000 km^2 occupied by 2.6 million inhabitants. Very many populated islands in the Pacific are less than 10 km^2 while some, especially the atolls, are less than 1 km^2. The economic and social well-being of small island countries, not least the very many located in the Pacific, are dependent upon the quality and quantity of their water. But the ability of small island countries to manage their water sector effectively is constrained by their small size and by their more limited human resource base. In many island countries, factors such as climate variability, increasingly variable rainfall, accelerating storm water runoff and increasing demand for water are so significant that their economic development and the health of their people are seriously threatened.

Two of the most important climatic influences on the Pacific islands are tropical storms and El Niño Southern Oscillation (ENSO) episodes. During El Niño events, the low pressure zone which normally brings abundant rainfall to the west shifts eastward, with the potential of causing catastrophic droughts in Indonesia, Papua New Guinea, and other Melanesian islands. At the same time, the El Niño brings typhoons and storm surges into the central Pacific, affecting islands like Hawaii and French Polynesia. Under the reverse conditions – La Niña – it is the low equatorial islands of western Kiribati that can be seriously affected by prolonged droughts. In addition to current climatic variability, climate change is likely to have a great effect on small Pacific islands. Most models predict an increase in the frequency of El Niño episodes, an increase in the intensity of cyclones and a rise in sea level of 0.3 - 0.5 m.

The Dialogue concluded that priority and support needed to be given to a set of five strategic responses. First, to using the information from seasonal and interannual climate forecasts, noting that a number of initiatives are already under way in the Pacific region to provide useful forecast information to support decision makers. Second, to hazard and risk management programmes, recognising that vulnerabilities should be addressed by better risk management planning. Third, to vulnerability and adaptation assessments, under the auspices of the UNFCC, but with a greater focus on adaptation, rather than concentrating primarily on mitigation. Fourth, to a Pacific climate information and prediction system, building a concerted, regional approach to generate and communicate climate forecasting information. Fifth, to drought assessment and response.

To move action forward, the Dialogue partners have formulated an Action Plan to be implemented as part of the Pacific Regional Action Plan for Sustainable Water Management.

West Africa

The West Africa Region recognizes that it has faced a new climate context since the early 1970s. Records of rainfall and river flows confirm intuitive perceptions of increasing water scarcity, particularly in Sahelian countries.

The principle of subsidiarity dictates that regional efforts are complementary and add additional value to actions at national and local levels. So, the rationale of an adaptation strategy at the regional scale lies in mutual benefit and economies of scale. Benefits are foreseen to arise from the sharing of climate information at regional and transboundary-basin level, from identifying and sharing best adaptation practices and from implementing regional responses in shared (multi-country) ecosystems.

Box 4.5 shows how village communities around Lake Chad have adapted to the progressive shrinking of the lake. There are also examples of land-use planning based on risk and disaster management in the integrated planning for the Okavango Delta and Basin, and the National Disaster Management Project in Mexico.

4.5 Dialogue methodology assessment

The Dialogues themselves have been a useful contribution to improving participation, knowledge and skills. At their simplest, they give the message "We are taking action – you can too". They have brought together stakeholders from many different camps – often camps that do not commonly interact.

Box 4.4 Adaptation around Lake Chad.

Sarch and Birkett (2000) have compared livelihood responses on the south western shore of Lake Chad with the lake level fluctuations recorded by ground gauges, satellite imagery and radar altimetry. This shows that since 1972, the communities of the western lake shore have made important responses to the contraction and recent expansion of the lake. Two responses were mentioned frequently: resettlement and switching livelihood strategies. Each of the village communities involved in the participatory research explained that they had moved to their current village from a location further west. As the lake levels dropped during the 1970s and 1980s, the maximum extent reached by the lake each year receded eastwards towards the center of the lake basin. Village elders in each village explained how they had followed the lake shore and in some cases, had moved eastwards more than once. The second response that had been made in each of the case-study villages to the contraction of the lake was to diversify from relying entirely on fishing to farming the lake floor as the flood water receded. In the years 1978, 1984 and 1985 when there has been a significant, year-on-year, drop in the level of the lake, previously fishing villages have responded immediately by farming the emerging lake floor. Although each of the village communities described how they had initially been set up as fishing settlements during the 1970s and early 1980s, in 1993 the majority (54 per cent of households) of households relied on farming as their main source of income (Sarch, 1996). Many of the Hausa communities who had been attracted by the fishing opportunities of the 1970s explained how they had switched to farming as the lake shore contracted and revealed the moist soils of the lake floor around their fishing settlements. Of the 80 percent of Hausa households who had fished Lake Chad in the past, the majority (58 per cent) now relied on farming for more than a quarter of their annual income (Sarch, 2000).

In particular the Bangladesh dialogue has shown the benefits of initial surveys, capturing stakeholder views of the key issues and opportunities for their solution. They have shown the importance of networks for action – direct action on specific solutions, or consortia designing broader plans of action. Early engagement of key players, particularly those of high political standing, has been shown to be a key to future success.

Advocacy and awareness-raising has influenced river basin committees and government agencies and brought water-and-climate issues to the attention of the general populace and the politicians – so securing a broad and political basis for action. Raising awareness includes publications through the media, including radio, television, newspapers, journals and film. Practical examples of local action include Nagoya and the San Pedro and Lena basins. Other examples in community-based flood mitigation are Bandung City in Indonesia, the tsunami disaster reduction awareness programme in Papua New Guinea, and the NGO-driven floodwater campaign of the Rhine.

The Dialogues have shown there to be a large amount of knowledge already out there, but there are evident areas where this can be improved – particularly in consolidation and focus. Fruitful areas for action are seen to lie in common adaptation frameworks, baseline studies, international information sharing, integrated information systems and the piloting of adaptation options. Information systems on disasters have mushroomed in recent years, including Relief web, the Southern African Flood and Drought Information Network, the National Natural Disaster Knowledge Network (Nanadisk-Net) in India and the Australian Disaster Information Network (AusDIN).

Hazard (or vulnerability maps) are able to assist planners and managers in their prevention of serious damage through land-use planning and disaster management. Hazard maps are finding routine applications in several countries, including the US, UK, Japan, France, Norway and some developing countries. ESCAP/WMO initiated the Flood Hazard Mapping project for the Typhoon Committee area as a means to share information amongst member countries.

The Dialogues have also shown that there remains much still to be done on the knowledge base. Not least, there is seen to be much scope for research and development to improve the scale and focus of the climate models – to help planners to plan better, and to give primary stakeholders some sense of what might really be going to happen. Another potential focus of R&D seems to lie in adaptation. There are calls for integrated science programmes – linking climate to epidemiology, or linking food productivity under water shortages to calorific intake. There are calls also for the strengthening of the operational tools of the water manager. Here again, the direction is towards

The in-progress West African Regional Adaptation Strategy is framed around the principles recommended by UNFCCC in 1997, namely: prevention of losses by alleviating vulnerability; reduction of losses to a tolerable level (within absorptive capacity); spreading and sharing losses by distributing impacts to a larger scale; changing activities that are no longer viable; relocating activities or population groups; and restoration of vulnerable sites.

Seven inter-related axes of intervention are scheduled in the West African region:

1. to benefit from an improved understanding of regional climate change patterns and impacts in West Africa;
2. to improve awareness of the predictable impacts and relate these to the major development challenges;
3. greater involvement by the regional institutions of West Africa in the international Conventions on Climate Change and the Environment;
4. IWRM approaches, especially within the many shared river basin and aquifer systems that characterise the region;
5. strengthened capacity of the existing river basin organisations, and their capacity to absorb and implement the coping agenda;
6. strengthening existing early warning systems; and
7. a cautious but steady approach to implementation through the piloting of adaptation interventions, but within a framework that offers good opportunities for up-scaling, if successful.

Southern Africa

Participants at the Southern African Dialogue concluded that the region is already in trouble. Climate variability has caused untold suffering to the region in recent years and climate change has been projected to cause even more devastating economic, environmental, social and political impacts. Recent studies on the vulnerability of the water sector consistently show the region to become drier and warmer, resulting in water scarcity due to higher frequency droughts and deficits in water recharge, food shortage as a result of reduced yields and changing planting seasons, and increased diseases, particularly malaria, due to warming. The region is already experiencing more severe and more frequent occurrence of storms and floods (and associated infrastructure damage), and more severe winters. The poorest segments of society and economies are the ones that have and will suffer most as they have the least capacity to cope with effects of climate change impacts. The cost of preparing to deal with the impacts is recognized as being much less than those for mitigating the effects of impacts after the disasters have occurred.

It was recognised that some key actions have not yet been taken. The region does not yet have a robust water and wetland management framework in place. Various policies, plans and legislation - necessary for integrated management of climate, water and wetlands - are largely lacking. National, regional and international conventions are managed in isolation amongst the countries of the region. The region has dealt only with disaster management and not disaster preparedness, demanding resources after disasters have occurred. The capacity to deal with climate variability has been inadequate and the capacity to deal with climate change is even larger.

The Dialogue identified actions that can be taken. The region can only lessen impacts of climate variability and anticipated climate change if countries entrench a culture of pre and post-disaster management. This is achievable through an adaptation framework that deals with impacts and mitigates the suffering that they cause. For this to be achieved, the region needs to commit resources (financial and human) to the framework – to its adoption and to its implementation. It is recognized that resources can be accessed through international conventions, provided appropriate adaptation programmes are developed. Individually, single economies have low capacity to deal with the impacts of climate change. So the region needs to act together. The case is made that a Regional Adaptation Framework be implemented in a coordinated manner.

The Dialogue acknowledged that the time to act is now. The region will benefit if information that is already known can help direct planning - even if all the information needed is not yet available. The region can adopt continuous planning as more data emerge and evolve.

The key message issued from the Dialogue to the wider community is that "we are getting our act together!" Southern Africa has initiated a Dialogue to develop a regional Adaptation framework for the water and wetlands sectors, to obtain solid commitment from stakeholders and political buy-in, to enhance regional networking, and to develop a fund raising strategy. But the region needs support, identifying that the following are urgently needed for the framework to come to fruition: first, a Climate Change Global Adaptation Fund; second, relevant institutional and skills development in pre-disaster, during-disaster and post-disaster preparedness; third, technologies to cope with changes in climate, such as species varieties that can cope with climate change and flood management; fourth, international strategic alliances for sharing skills, experiences and collaboration in research. Fifth, there is a call that industrialized countries must ratify the Kyoto Protocol, so that earliest action is taken to reduce future impacts. The region is well aware that according to the IPCC (TAR, 2001) Southern Africa accounts for just 3.5% of the world's greenhouse gas emissions but it is the most vulnerable subcontinent to climate change. What price the polluter pays principle?

integration – merging climate with other factors so that it can be assessed in a wider context during decision-taking. All these activities depend on data. Over the years, many hydrological observation stations in developing countries have fallen into disrepair and disuse. Restoring and extending the hydrological data base is a pressing need that will dictate the pace of adaptation progress in many countries.

Ultimately, the Dialogues have recognised the importance of the skills of those engaged in action. In many places the skills base is short and already under pressure. Nothing will work if there is not sufficient technical and operational capacity and skills in critical areas. Education and training will play a key role in establishing capacity. Locally, significant examples of capacity building are underway through the Asian Urban Mitigation Program (AUMUMP), the UN-ESCAP programme on Flood Mitigation and Preparedness in Asian River Basins and the SPHERE project in Albania.

Finally, the dialogues will benefit from guidance on the preparation of the state of the art on water and climate, on bringing together different stakeholders, from a compendium on best practices and coping actions and from a compendium on external support, including capacity development.

4.6. Conclusions and recommendations

DWC's efforts to stimulate interchanges between the water and climate professional communities have been productive in some areas and revealing in others. There is no doubt that much more is needed to combine the experience and expertise of the two professions for the benefit of future water resources management and the safeguarding of present and future populations. The Coping Compendium is only a taste of what can be put together to help vulnerable people to respond to climate challenges. The co-operation will continue and expand, and the Dialogue process needs to evolve further linking activities at basin, country and regional level. From its activities over the last two years, DWC has been able to provide some pointers for carrying the co-operative process forward.

1. The three levels of stakeholder dialogues have both individual and synergistic merits. Ideally, a vulnerable community needs support from a local, a national and a regional dialogue. The stimulus for setting up the dialogues can come from any level, but will probably be most effective if it originates at local level, through a river basin authority or community-based organisation seeking to find solutions to threats perceived by local communities. Early involvement of higher authorities in the local dialogue can then be the impetus for a national dialogue, where it does not already exist.
2. The focus of all the Dialogues should be on local coping actions with national and regional support (technical assistance, information sharing, early-warning systems, resource mobilisation, . . .). Development of methodologies for assessing and comparing vulnerability to climate variability and climate change at local level will be important in prioritising external support. Lack of agreed methodologies should not, however, inhibit local self-help programmes, which can go a long way towards coping with climate extremes.
3. The Coping Compendium now offers a preliminary menu of actions. There is scope to develop it into a practical tool for decision-making and strategy development. For that to happen it needs feedback and pro-active participation. Case studies, criticisms and new experiences are needed to help to expand the cryptic list of options into specific examples and ways of linking adaptive capacity to the selection process.
4. Public and political awareness of present and future threats from climate variability are crucial factors in spurring action. Advocacy and awareness-raising campaigns need to be part of Dialogue activities at all levels. DWC and any successor organisation must continue to report on the successes of adaptation strategies all around the world, and to draw comparisons with the costs of inaction. That means compiling dossiers from all the ongoing and future dialogues. It also implies the need for development of appropriate indicators to demonstrate progress, be it in saving lives and money or speeding progress towards other development goals.

Mediterranean

The Mediterranean basin is a region containing northern (European Community) countries, developing countries (North Africa), and countries in transition, such as Turkey. Simplistically, it divides into three sub-regions (North, South, East) along the lines of climatic, institutional and political criteria. The Member States of the EC fall under the governance and framework directives of the Union, an institutional framework absent in the other sub-regions. It is a region in which water is to be found very high up the political agenda, not least in the Middle East. Droughts are a natural characteristic of the region. South and eastern Mediterranean countries are more vulnerable than northern countries.

Droughts have occurred more frequently and more severely during the 1980s and 1990s. It is often reported that this is in conjunction with climate change, but evidence of the link is not yet conclusive. Tree rings shows that similar prolonged droughts have occurred in the past. Climate change, drought and desertification are inter-related but are often talked about interchangeably. This adds to confusion of cause, and increases uncertainty for the future. The long coastline of the Mediterranean Sea, with wetlands of unique ecological value, numerous endemic species and unique coastal and marine habitats heightens the vulnerability of the region to sea level rise.

The Dialogue determined that climate change adds an additional factor of uncertainty. As such, it is actually proving a barrier to action in integrated water and coastal zone management. Lack of consensus is hindering the ability of society, decision-makers and financers to move forward coherently. On a national level, some strategies to mitigate climate change are in place. Italy has evolved a national public-private platform on water allocation and spatial planning. But there is little action at the regional level in mitigation, and less in adaptation. The Dialogue participants saw potential for a regional strategy that integrated the objectives of the UNFCCC, the Ramsar Convention, the Barcelona Convention and the local participatory implementation of Agenda 21, building on the impressive stakeholder networks already in place.

The main issues to be overcome lay in closing the gap between global science and local action, in justifying short-term costs on the returns of long-term benefits, and in addressing the adaptation agenda. On the former, action could not await a consensus conclusion on climate change impacts, but could instead move forward through a dynamic approach based on incremental scenarios. Working regionally, this could be advanced through transparent information exchange between countries, and a common framework for monitoring and impact assessments. On the latter, adaptation to climate variability is certainly not new – the region has always adapted to changing circumstances. But it is climate change that introduces additional uncertainy, with unknown consequences for water management.

Three priorities were outlined for adaptation strategies, taking the overall approach of introducing gradual change to reduce the risk of a 'big shock' further down the line: first, reducing the risk of hydro-meteorological events; second, closing the gap between water supply and demand; and third, balancing the stakes between people and nature. These strategies could realistically be composed of actions in the areas of monitoring and forecasting, dam design and operations, economic instruments, drought action plans, desalination, flood management and wetland protection.

Chapter 5: External Support

5.1 The case for supporting coping actions

Chapters 3 and 4 have stressed the importance of local adaptive capacity when judging the vulnerability of a community or region to climate extremes and when selecting appropriate coping actions. Adaptive capacity is closely linked to the level of development in the region concerned and the resource constraints facing local government institutions. A community's capacity for self help will frequently be limited by lack of resources and the day-to-day pressures of a subsistence lifestyle. As well as tailoring their coping strategies to local strengths and weaknesses, developing countries need to tackle the constraints through capacity building, coupled with technical and financial support. For that, the governments themselves need external support. Regional and international knowledge/ research organisations can help with training and knowledge sharing; UN agencies and international organisations with links to climate or disaster relief have regional and sometimes national offices that offer help via workshops, information networks and training courses; and for governments integrating adaptation to climate threats with their other developmental priorities, financial support may be available through their partnerships with multilateral and bilateral donors. Finely targeted support for mitigation and some adaptation may also be accessible through the Global Environmental Facility (GEF).

In this Chapter, we explore the avenues available to developing countries, or agencies within those countries, seeking support to build their adaptive capacity and to implement appropriate coping strategies. There are powerful reasons, over and above the aims of normal overseas developmental assistance, why requests for support for adaptation to climate change and climate variability should be sympathetically received by donors, relief agencies and other external support agencies.

1. **The Polluter Pays Principle:** However contentious the detailed arguments may be about causes of climate variability and change, there is no room for doubt that the increase in greenhouse gases is a factor in the speeding of the hydrological cycle that is bringing more and more hydro-meteorological disasters. Greenhouse gases come predominantly from the industrialised nations, but the effects are felt disproportionately in the developing world. The "polluter pays principle", under which national governments collect taxes and charges for cleaning up municipal and industrial wastes, is equally applicable on a global scale. Support for mitigation and adaptation is a channel for the polluters to pay their dues.

2. **Safeguarding development goals:** Developed and developing countries are jointly committed to global goals on poverty reduction and sustainable development. As we have seen, years of progress towards those targets can be wiped out by a single disaster, or a succession of extreme events. Precautionary investments in disaster preparedness and adaptation will help to protect developmental progress.

3. **Pre-emptive relief:** Support for local adaptation pays dividends in savings on relief and recovery costs when the extreme storm, flood or drought arrives.

The floods in Mozambique in 2000 and 2001, which directly or indirectly affected about 4.9 million people, displaced 550,000 people and claimed 700 lives along the Limpopo River, raised awareness and recognition of the widening range of sudden threats. In 2000, in response to the first flood, the Southern African Development Community (SADC) created the Strategy for Flood and Drought Management and approved the SADC Shared Watercourse Systems Protocol, which offers a framework of implementing transboundary management over the region. A Post-Emergency Reconstruction Programme was started in Mozambique and a Joint Operations Technical Committee established to share data/information on reservoirs. South Africa started discussions on a Disaster Management Bill. In all, the international community provided US$100 million in emergency assistance and relief, and subsequently pledged exceeding US$450 million for rehabilitation. While it would be unwise to jump to extreme conclusions, it is certainly relevant to note that in 1999, before the actual flood occurred, the Mozambique government had unsuccessfully requested US$3 million for immediate disaster preparedness activities for the upcoming rainy season.

5.2. Global recognition

The need to address climate change and increasing climate variability is quite a new issue in the global water debate. Though the increase in extreme events was identified as a new challenge for water managers in Agenda 21 of the 1992 UN Conference on Environment and Development (The Earth Summit) in Rio de Janeiro, this was not explicitly linked to climate change or increasing climate variability. Chapter 18 of Agenda 21 only notes that the hydrological cycle, including floods and droughts, has become more extreme in some regions and that the impacts have become more dramatic. Agenda 21 continues with the need to establish national and basin-wide databases. It recommends a comprehensive set of measures for the water sector which, as the Implementation Plan of the 2002 World Summit on Sustainable Development states, is still very valid today. The recommendations include:

- Develop flood and drought management, including risk analysis and environmental and social impact assessment;
- Establish and strengthen the institutional

capabilities of countries, including legislative and regulatory arrangements, that are required to ensure the adequate assessment of their water resources and the provision of flood and drought forecasting services;

- Review existing data-collection networks and assess their adequacy, including those that provide real-time data for flood and drought forecasting;
- Provide forecasts and warnings of flood and drought to the general public and civil defence;
- Develop long-term strategies and practical implementation programmes for agricultural water use under scarcity conditions with competing demands for water;
- Monitor the hydrologic regime and related climate factors, especially in the regions and countries most likely to suffer from the adverse effects of climate change and where the localities vulnerable to these effects should therefore be defined;
- Formulate specialised programmes focused on drought preparedness, with emphasis on food scarcity and environmental safeguards;
- Develop and apply techniques and methodologies for assessing the potential adverse effects of climate change, through changes in temperature, precipitation and sea level rise, on freshwater resources and the flood risk;
- Initiate case-studies to establish whether there are linkages between climate changes and the current occurrences of droughts and floods in certain regions.

Agenda 21 recommended improving research and monitoring in the water sector, awareness raising activities, spatial and temporal downscaling of risk assessment tools and development of local action through practical coping. It did not at that stage include specific recommendations to deal with increasing temporal variations, unexpected freak events, or the impacts on coastal zones of sea level rise, storm surges and typhoons. Also, most importantly, Agenda 21 did not link the observed changes in hydrological regimes with climate change and increasing climate variability.

Since 1992, the water sector agenda has moved on. A succession of international conferences and gatherings focused more and more attention on water scarcity. That led to the **Second World Water Forum** in The Hague in 2000 adopting water security as one of the seven challenges for the sector. Later in the same year, validated evidence of the increasing frequency of hydro-meteorological disasters affecting hundreds of millions of people led to the **UN Millennium Declaration (September 2000)** promoting co-operation among agencies to reduce the number and effects of natural and man-made (hydrological) disasters.

The Millennium Declaration call to reduce the number of casualties led to a gradual change away from relief in response to disasters towards enabling strategies to cope with and manage them and to assist vulnerable communities in disaster-prone areas to prepare for disasters. The disaster agenda is now expanding even further, with the insurance sector developing instruments for risk spreading and risk insurance.

The all-important linking of climate change and variability with water management came at the end of 2000. At a meeting of the Dialogue on Food and Environment, a group of water experts called for the establishment of a similar ***Dialogue on Water and Climate*** (DWC). A year later, following strong representations from DWC, the **Bonn Freshwater Conference** (December 2001) finally put water and climate change/variability together on the global agenda.

The World Summit on Sustainable Development in August/September 2002 in Johannesburg endorsed Agenda 21, including the recommendations for the water sector to deal with increasing floods and droughts. It also built upon the UN Millennium Declaration by emphasising international, regional and national collaboration as well as partnerships involving governmental, non-governmental and private interest groups. The Plan of Implementation for the WSSD promotes partnership cooperation at all levels, including public-private partnerships to implement the Programme of Action.

The United Nations Framework Convention on Climate Change Eight Conference of the Parties (UNFCCC-COP8) held in Delhi in November 2002 took an important step to lift adaptation issues higher on the global agenda. It also added to the convergence of views on the importance of a multi-pronged and multi-stakeholder approach to adaptation. More particularly, it accepted that the past approach of focussing on mitigation of climate change and limiting funding support to incremental costs attributed only to climate change is too restrictive. COP 8 observed that even if mitigation efforts could bring greenhouse gas emissions down to the level of 1990 immediately, the trend of increasing global warming would only taper off after several decades. This understanding makes the climate community partner to sectoral adaptation actions, as it has become increasingly apparent that actions for coping will mostly take place within a sectoral framework.

So, the need to respond to climate-induced hydrological changes has become a multi-stakeholder challenge. It means addressing physical/structural, economic, social, environment and institutional issues and requires collaboration between governments, NGOs, the private sector and the science community. The water resources community has to start factoring in hydrological changes due to climate into its policies, planning, designs, implementation and management activities. The disaster-management community is seeking to include prevention-oriented preparedness alongside its relief activities. At the same time, the rapid growth in claims from weather-related damages has encouraged the insurance world to start looking at new instruments to spread risks. For the climate community, these changes mean forging new partnerships and finding new approaches that will bring practical weather forecasting and climate prediction data to water managers and others involved in adapting to hydrological extremes.

5.3. Knowledge, research and capacity building support

A number of international agencies have climate as their primary focus of attention; the increasing attention given to "water and climate" in the international arena has led other development support agencies to add climate-related activities to their agendas; and new partnerships and networks have been formed specifically to provide information support or conduct research on climate issues.

It would be helpful if there was a directory or source book to guide those seeking programmatic support for their adaptation strategies to find the most appropriate agencies. Unfortunately there is no such publication, though many of the agencies' websites do have copious links to others, enabling enthusiastic surfers to compile their own list of potential partners. Table 5.1 is a starting point for such a tour. Funding support is not listed there; it is discussed separately in section 5.4. The table lists some of the main UN agencies and international networks, along with their climate-related areas of focus and the types of activity in which they may become engaged. In some instances, the "support" for awareness raising or information sharing is not project-related, but a global or regional activity from which all can benefit. In other cases, agencies such as UNESCO-HELP or UNDP may associate themselves with individual projects to provide specific help in capacity building or applied research.

The list is not a complete one and DWC issues an open invitation to those who may have been inadvertently omitted to come forward with their information. We intend Table 5.1 only as a starting point and hope that a project may soon be started to compile a comprehensive source book on Water and Climate. This may be one of the tasks assigned to the proposed Water and Climate Associate Programme (WCAP) (see section 6.6). The Associate Programme might well take as a starting point some of the knowledge dissemination outputs already developed by DWC. These include a training package for water managers on climate change and climate variability, which needs to be further developed and tested through selected training networks. DWC also prepared an interactive bibliography on water and climate, which is currently accessible through the web site (www.waterandclimate.org) and is included on the CD-ROM that accompanies this report. The Dialogue also facilitated development of some vulnerability assessment methodologies and tools (section 3.1). This work too needs to be taken further to demonstrate their applicability in different situations.

5.4. Financial support for coping and adaptation

The development of capacity to cope with expected future risks will in many cases require substantial external resources to reduce the vulnerability and increase the resilience of those most at risk. In principle there are two ways that external support can be channelled:

a. Via national planning processes that define a demand for external financial support through normal development assistance channels;

Table 5.1 Overview of some external support agencies

		Area of focus				Type of activity				
	Organisation	Vulnerability	Adaptation	Disasters	Water Climate Research	Awareness raising	Information sharing	Research & Methodologies	Capacity development	Implementation
UNITED NATIONS AGENCIES	WMO			●	●	+	+++	+++	++	
	WCP				●		+++	+++		
	UNESCO-HELP	●	●		●		++	+	+++	+
	UNDP		●	●			+++	+	+++	+
	IPCC	●	●	●	●	++	+++	+++		
	WHO	●	●		●	+++	++			
	ISDR			●		++	+++	+++	++	
INT'L NETWORKS	WB*	●	●				+	+++		
	IUCN/IISD/SEI	●	●		●	+	++	++	++	++
	VARG	●	●			+++	+++			
	Pro-Vention							+++	+++	
	Red Cross	●		●					+++	++
	AIACC		●				++	+++		
	IRI	●		●	●	+	+++	+++	++	

Key to symbols: + some activity ++ regular activities +++ a main area of activity

*In the case of the World Bank, the symbols indicate assessment methodology development activities of the bank in the field of water and climate

International agencies supporting water-and-climate activities

WMO: The **World Meteorological Organization** is a UN agency that has climate as the central focus of its agenda and is a co-sponsor of many related activities, including a number of those in Table 5.1. WMO coordinates global scientific and operational activities to allow increasingly prompt and accurate weather and hydrological information and other services for public, private and commercial use. The agency assists its members and in particular the National Meteorological and Hydrological Services (NMHSs) in the development of techniques to assess and combat drought, floods and other extreme events. This is achieved through a number of scientific and technical programmes related to the mitigation of natural disasters and risk management supported by the participation of NMHSs in association with Regional Specialized Meteorological Centres (RSMCs) world-wide and in collaboration with other national and private-sector organizations. The Hydrology and Water Resources Programme assists the national hydrological services of member countries to assess the risk of, and forecast water-related hazards, in particular major floods and droughts. Of particular interest is the monitoring and prediction of climate-related natural disasters associated with the El Niño and La Niña phenomena.

Website: http://www.wmo.ch/

WCP: The interagency **World Climate Programme** was established after the first World Climate conference in Geneva in 1979. Co-sponsored by WMO, UNEP, UNESCO and ICSU, it has four main components, providing governments with background data and strategic guidance on coping with climate variability and change. They are:

WCDMP: World Climate Data and Monitoring Programme
To facilitate the effective collection and management of climate data and the monitoring of the global climate system, including the detection and assessment of climate variability and changes;

WCASP: World Climate Applications and Services Programme
To foster the effective application of climate knowledge and information for the benefit of society and the provision of climate services, including the prediction of significant climate variations both natural and as a result of human activity;

WCIRP: World Climate Impact Assessment and Response Strategies Programme (WCIRP)
To assess the impacts of climate variability and changes that could markedly affect economic or social activities and advise governments thereon, and contribute to the development of a range of socioeconomic response strategies that could be used by governments and the community

WCRP: World Climate Research Programme
To improve the understanding of climate processes for determining the predictability of climate, including its variability and change, identifying the extent of human influence on climate and developing the capability for climate prediction.

WCP has provided advanced climate database management systems to many countries, especially developing countries, with applications in several areas of disaster mitigation, especially drought.

Website: http://www.wmo.ch/web/wcp/wcp-home.html

UNESCO-HELP is an initiative to establish a global network of catchments to improve the links between hydrology and the needs of society. Hydrological scientists, water resources managers and water law and policy experts are being brought together to work on practical water-land resource management problems. Dialogue with stakeholders is fundamental to the implementation of HELP's "bottom-up" approach. HELP is a problem-driven and demand-responsive initiative which addresses five key policy areas:

- water and climate
- water and food
- water quality and human health
- water and the environment
- water and conflict

HELP is a UNESCO-led initiative in close co-operation with WMO and is being implemented through several partnerships with a number of other agencies and programmes. A network of 24 pilot-phase experimental basins have been established to collect physical (hydrological, meteorological, ecological) and non-physical (sociological, economic, administrative, legal) data in large catchments in the USA, Canada, Mexico, Puerto Rico, Panama, Brazil, Peru, France, the Danube in 5 countries in Europe, Germany, UK, South Africa, Mozambique, New Zealand, Australia, Thailand and Vietnam, the Mekong in 6 countries in Asia, India, Japan, Aral Sea, Sri Lanka and China.

HELP will provide:

- new data, improved models
- new scientific (process hydrology) understanding which is more integrated with policy and management
- a strong field component of integrated science-policy management through a continuous dialogue with stakeholders (bottom-up approach)

There are plans to add new common study basins and both new technical and non-technical information for the 2nd World Water Development Report to coincide with the 4th World water Forum in 2006. Regional HELP Centres are planned.

The HELP criteria for consideration as a future experimental basin are available at the website.

Website: http://www.unesco.org/water/ihp/help.

UNDP: The **United Nations Development Programme** is developing guidelines for adaptation plans in the water sector and has acquired funding for pilot testing the guidelines in Mozambique, Tanzania and Vietnam.

In partnership with regional and global centres of excellence and agencies such as DWC and IRI, UNDP, with SIDA's assistance, will assist the countries in implementing learning by doing capacity development in the water and climate change sector. These efforts will support the formulation of adaptation and coping strategies and integrate water issues and impacts into local and national development instruments. The agency says that on the ground capacity building activities will span human, institutional and systemic dimensions and highlight innovative governance systems that are robust, flexible, and adaptable and can enable water institutions to deal with new challenges presented by climate variability and climate change in a sustainable development framework.

UNDP Country Offices will play a key role in promoting multi-stakeholder dialogue, assessing the impact of climate variability and change on integrated water resource management (IWRM) and water governance, and strengthening national adaptive capacities. This initiative represents activities that are first of their kind. From the climate change perspective, National

b. From earmarked GEF support to adaptation processes

Both of these systems can potentially provide financial support to the most vulnerable communities that can make systematic and structural differences to their capabilities to cope with climate change and climate variability. In both cases, however, there is a need for changes to the principles and procedures on which this support is provided.

National planning processes and development assistance too often focus on immediate problems and demand immediate measurable benefits that are a barrier to the longer term and preventative nature of adaptation and coping processes. The GEF has tended to focus exclusively on environmental benefits (narrowly defined) that are international in character. It is to be hoped that funds newly allocated to adaptation measures will recognise local level benefits and non-environmental (especially social and livelihood) gains.

There is a particular need for the governments of the OECD countries that largely determine development assistance policies and GEF processes to ensure that activities designed to enhance coping and adaptation capabilities of the most vulnerable are included in these systems and that the criteria on which they are assessed are modified to reflect their basic character. These issues are developed in more detail in the next sections.

5.4.1. National planning process

To qualify for external financial support from bilateral or multilateral sources a request has to pass through the normal national planning procedures. For LDCs this implies that the activities have to meet the following criteria:

- considered a political/policy priority
- based upon a sound knowledge base
- institutionally anchored
- based on a development strategy
- including capacity development
- specifying implementation mechanisms and capabilities

In addition to these national criteria in fields related to water management or environmental issues, external financiers have requirements that favour projects which are part of and contribute to:

- the National Sustainable Development Strategy
- the National Environmental Action Plan
- the national Poverty Reduction Strategy Plan (PRSP) and livelihood strategies
- the achievement of the Millennium goals

There are powerful arguments in this report as to why adaptation to climate variability and change supports and safeguards progress towards achieving these other developmental goals. Considerable advocacy work is needed though before governments and donors make that link automatically. In particular, adaptation frequently falls under the mandates of a number of institutions, leading to problems of co-ordinaton of donor funds making it difficult to identify it as a national priority.

5.4.2. Global funds

GEF Funds for Mitigation and Adaptation

The financial entity for the Climate Convention (and also the other major multilateral environmental agreements – namely the Convention on Biodiversity and the Persistent Organic Pollutants is the Global Environment Facility (GEF) which has been funding climate change activities for 10 years (it has spent about US$1 billion on climate change activities in that time). However, most of this has been to fund mitigation actions. GEF was mandated to start spending on adaptation (provided it contributes to mitigation) only after COP-4 (Buenos Aires) under stage 1 and 2 out of the following 3 stages of adaptation activities.

Stage 1: Planning and studies only. Funded Vulnerability and Adaptation studies as part of National Communications

Stage 2: Capacity building only. Two projects funded in Pacific (PICAP) and Caribbean (CCAP).

Stage 3: Adaptation measures. Not funded yet.

Since the second replenishment of GEF was approved (in Beijing in October 2002) officials are still preparing guidelines for the funding of adaptation activities (e.g. whether and how to fund Stage 3 activities) from GEF core funds.

At COP 7 in Marrakech, Morocco in November 2001 3 new funds were created, all of which have relevance for adaptation. All the funds will be administered through the GEF. These funds are:

1. Least Developed Countries National Adaptation Programme of Action (NAPAs) in the 49 least developed countries (LDCs). This programme has received about US $15 million mainly from Canada, Ireland and UK) from which LDCs will receive around US$720,000 per country to do their NAPA. It is expected that each LDC will prepare their NAPA within the next 12-18 months. The NAPAs are to identify specific, priority adaptation actions for funding through the LDC Fund.
2. Special Climate Change Fund: This new fund will fund a number of activities including both mitigation and adaptation. However, this fund will only become operational from 2005. A few donors (EU, Norway, Switzerland, Canada) have made a political commitment to provide $400 millon/yr into

communications under the UNFCCC will provide a starting point for developing national adaptation strategies. Project activities will include learning from UNDP-GEF Climate Change Adaptation Policy Framework.

UNDP at the request of the countries and in partnership with, among others, the local ministries of water resources management and meteorological services will convene multi-stakeholder workshops in each country. The workshops will take stock of the potential adverse impacts of climate variability and climate change and explore options to addressing them within the national development strategies and options for developing integrated knowledge networks and comprehensive human and institutional capacities.

Website: http://www.undp.org

IPCC: The Intergovernmental Panel on Climate Change has been established by WMO and UNEP to assess scientific, technical and socio-economic information relevant for the understanding of climate change, its potential impacts and options for adaptation and mitigation. It is open to all Members of the UN and of WMO. IPCC has become the world authority on climate change and its conclusions are quoted extensively throughout this report. It provides the underlying policy guidance requested by governments for dealing with climate change. IPCC Working Group 1 works on science, Working Group 2 on Impacts and Working Group 3 on Mitigation (green house gas emission reduction).

Presently IPCC is considering adjusting its agenda to focus more on the impacts of climate variability and climate change on for example the water sector, and paying more attention to addressing coping strategies.

Website: http://www.ipcc.ch/index.html

WHO: The World Health Organization is conducting research on climate change, adaptation and human health and it publishes the results in the form of fact sheets on its web site: http://www.who.org.

ISDR: The United Nations International Strategy for Disaster Reduction is a global framework for action seeking to enable all communities to become resilient to the effects of natural disasters and to proceed from protection against hazards to the management of risk through the integration of risk prevention into sustainable development. ISDR supports methodology development, initiatives in the field of adaptation strategy development at the regional and national level, initiatives to improve risk management, risk sharing and disaster preparedness. An important contribution of is improving the global disaster database. ISDR organises the United Nations World Disaster Reduction Campaign on a different theme every year. This is an important global advocacy event with national activities helping to build the societal base for action to prepare for and respond to disasters.

Website: http://www.unisdr.org/.

WB: Among the many activities of the World Bank are development of a methodology for rapid vulnerability assessments, and its own National Adaptation Strategy Studies. The Bank sees a need to develop rapid assessment tools which place climate change in the development context and aid decision-makers in the identification of adaptation options. The aim is that rapid assessments should draw on existing scientific knowledge on climate change impacts and help to evaluate their implications for regions and economic sectors. By synthesising existing knowledge and making it available to decision-makers, assessments should help to identify the sensitivity of various societal groups and economic sectors to climate change, establish the likely bio-physical framework of change induced by global climate change, and define options to optimise the socio-economic and political environment to allow for adaptation of the identified vulnerable societal groups or sectors in the projected framework of change.

Website: http: //www.worldbank.org

IUCN/IISD/SEI: The Task Force on Climate Change, Adaptation and Vulnerable Communities, set up by IUCN-The World Conservation Union, the International Institute for Sustainable Development and the Stockholm Environment Institute, provides guidance on community based approaches for adaptation. The basis of the initiative is to leverage the experience and expertise in the fields of disaster prevention, natural resource management (including water) and sustainable livelihood to the climate change adaptation agenda. The overall objective is to encourage and assist countries in developing strategies to reduce vulnerability of local communities to climate-related disasters and climate change. The initiative is to help local partners in the development and formulation of activities under the three funds by testing out and demonstrating new integrative approaches to adaptation.

Through the Water and Nature Initiative, IUCN is mainstreaming an ecosystem approach into catchment policies, planning and management. The Initiative responds to the Water and Nature Vision, and the call for moving from vision to action voiced at the 2nd World Water Forum. The climate change portfolio within the Water and Nature initiative undertakes activities that are innovative and targeted at guiding future investments and actions in water resources management and nature conservation. The initiative focuses on building national and regional coalitions on climate change, and assisting countries in taking positive and practical action to incorporate the uncertainty of climate change into decision-making and management of water resources.

Website: http://www.iucn.org/

VARG: The Vulnerability and Adaptation Resource Group is an informal network with participation from bilateral and multilateral development organisations including UNDP, the World Bank, DFID, USAID, IIED, DGIS, EU, IISD, CIDA, IRI and IUCN. Its primary purpose is to create a learning environment for its member organisations to share experiences and co-ordinate climate change adaptation efforts, enhancing efficiency and cost-effectiveness by avoiding duplication and promoting the use of concepts that have proved successful. The ultimate goal is that climate change concerns and adaptation activities are automatically integrated into the development planning of its member organisations.

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Pro-Vention: The Pro Vention Consortium includes the World Bank, the Red Cross and representatives of private insurance groups. Its activites encompass three areas of risk management: risk identification, reduction and transfer. Risk identification includes hot-spot assessment studies and training of emergency managers. Under risk reduction an evaluation is being carried out in Mozambique, Honduras, Bangladesh and Turkey on disaster recovery. Another issue is the vulnerability of cities and small countries, with studies in Malawi and Bangladesh. On risk transfer, Pro-Vention collaborates with large insurers on data and info provision, is working on a reinsurance pool in Central America and has found that micro-finance and micro-credit do not work very well during disasters.

Website: http://www.provention.org

this new fund. Nothing was agreed on operationalizing this fund at COP 8 in Delhi. The Fund will be further discussed in Milan in December 2003.

3. Adaptation Fund under the Kyoto protocol: This will be filled from proceeds of the "Adaptation Levy" (2 %) placed on transactions approved under the Clean Development Mechanism (CDM) of Carbon Trading. Thus the amount coming into this fund will depend on the volume of CDM transactions and no funds will be available before the first round of CDM transactions are approved by the CDM Board (that is not before 2008). The CDM Board was set up and started its activities at COP 8 in Delhi in October 2002. This fund will support "concrete adaptation" measures.

5.4.3 NAPAs, Adaptation Plans and the water sector

In the course of the next two years, in-country teams will prepare National Adaptation Programmes of Action (NAPAs) in LDCs and Adaptation Plans in other countries under their National Communications. These NAPAs and Adaptation Plans can include coping measures for the water sector, provided they are linked to climate change (incremental costs only) and contribute to global mitigation. NAPAs and Adaptation Plans will be eligible for funding through the GEF (either through the GEF core funding – Stage 3, or through the other funds located at COP-7). Funds are likely to become available as from 2004/05 onwards. It is paramount that water policy makers and managers fully engage in these processes, even where they fall under the remit of another ministry – typically environment, as they will be a major route through which both a higher profile and additional resources for adaptation measures in the water sector will be realised.

There are clearly severe limitations on the use of these funds, including:

Release after 2005
Adaptation funds will only become available from 2005 onwards. Before then submissions of water sector managers for external support can be prepared and assessed.

Only for mitigation and mitigation related activities
The following water sector coping activities do not (yet) qualify for GEF LDC Adaptation Fund support:

– precaution and protection: structural measures such as storage or dikes and non structural measures such as spatial planning measures, legislation and research.

– preparedness: early warning systems, disaster preparedness, forecasting research;

– risk sharing and risk management: insurance systems

– adaptation of lifestyles and water-related production activities in agriculture, industry etc.

– awareness raising

– methodology development and research on vulnerability

They do not qualify because they do not contribute to mitigation of greenhouse-gas emissions. These activities need to seek financing from other (sectoral) multilateral or bilateral funding. An exception is hydropower generation where it could be argued that the hydropower dam will contribute to mitigation.

NAPAs under Central Ministry
Another complicating factor is that the National Focal Points for GEF and the Climate Convention, which are the organisations responsible for the NAPA and the National Communications, are normally housed in the Ministry of Environment. Developing a coherent programme for adaptation requires integrating climate change (variability) concerns into the activities of several different ministries. To make the National Focal Points more accessible recommendationfor the water sector it has been suggested that Focal Points should come under a central Ministry such as Planning or Finance. Bangladesh has found another noteworthy example: the government has established an inter-ministerial committee of the Ministries of Environment, Water and Disaster Management to addressing adaptation issues.

5.4.4. Facing reality

The reality for the water sector is that it is difficult to find external support for adaptation activities. As a result, Bangladesh, for example, has decided not to consider long term implications of climate change (and climate variability) in the national water management plan currently under preparation. Instead it has labelled issues related to climate change as a knowledge gap, even though the country is recognised as one of the most vulnerable countries in the world to climate change and climate variability. Recent moves towards both a coastal zone policy and an adaptation strategy are in large measure addressing this issue directly. Ghana prepared a national water resources adaptation plan linked to changes in hydrology, but has so far failed to access GEF funds. Instead, the government is seeking external funding through its own national planning system.

Though giving importance to adaptation and mitigation is an important new challenge for water managers, there is a long way to go before national water sector coping plans are incorporated into NAPAs and before external support is available for the implementation of the NAPAs.

To bridge the gap between the needs for external support from developing countries and the inability of existing mechanisms to provide that support, the

Red Cross: The Red Cross/Red Crescent Centre for Climate and Disaster Preparedness was established in June 2002. The Centre is undertaking awareness raising, advocacy and capacity development on risk management and disaster preparedness at community level through the national Red Cross or Red Crescent societies.

In 2002 and 2003 the five first assessments are taking place in Ethiopia, Vietnam, Mozambique, Nicaragua and the Pacific. The assessments aim to lead to Disaster Preparedness programs that will increase awareness about possible impacts of climate change and climate variability, improve the protection measures at community level and improve community level early warning. The overall aim is to strengthen the resilience of vulnerable people. Already in Vietnam and Nicaragua the programs that emerged from the assessments are funded and ready to be implemented.

Website: http://www.icrc.org/eng

AIACC: Assessments of Impacts and Adaptations to Climate Change is a global initiative to advance scientific understanding of climate change vulnerabilities and adaptation options in developing countries. It was developed in collaboration with the UNEP/WMO Intergovernmental Panel on Climate Change (IPCC) and funded by the Global Environment Facility (GEF). By funding collaborative research , training and technical support, AIACC aims to enhance the scientific capacity of developing countries to assess climate change vulnerabilities and adaptations, and generate and communicate information useful for adaptation planning and action. AIACC is implemented by UNEP and executed jointly by START and the Third World Academy of Sciences (TWAS). In addition to GEF finance, collateral funding has been provided by the US Environment Protection Agency, US Agency for International Development, World Bank and participating institutions in developing countries.

AIACC is providing support to 24 regional study teams to conduct three-year investigations of climate change impacts, adaptation and vulnerability in 46 developing countries, in which more than 235 developing country scientists participate. The studies are diverse in their objectives but include water resources, livelihood and health. The anticipated outcomes include wider understanding of climate change issues among stakeholder groups in developing countries.

Website: http://www.aiacc.org

IRI: the International Research Institute for Climate Prediction was established in 1996 at the Earth Institute of Columbia University in New York, USA. It aims to advance sustainable development and reduce poverty in developing countries by linking science to society through the application of research on climate variability. That means using climate forecasts to improve management of climate sensitive sectors such as agriculture, health and water resources. IRI says that climate information and skilful climate forecasts have the potential not only to help developing countries cope with climate fluctuations but also to assist them in adapting to long term climate change. The institute is working on tailoring seasonal and inter-annual climate forecasts to local needs by training people at country level through the establishment of partnerships, including local universities, local and regional organisations such as the Drought Monitoring Centre Nairobi (DMCN), WMO regional offices, Asia Pacific Network for Global Climate Change, the Meteorological Service in Brazil, and others.

Website: http://iri.columbia.edu

international financial support community is urged to encourage mainstreaming climate concerns into the development process. To this end, current bilateral, multilateral and UNFCCC-based financial support should aim at reorienting current practices and remove barriers to adaptation strategies that build resilience to climate extremes into water development programmes. This is of practical importance to the development of coping and adaptation strategies at the community level, where people (and especially poor people) cannot afford the luxury of separating those activities from the mainstream of their lives and the development of their livelihoods.

To resolve these issues it is recommended that a working group will be formed, consisting of representatives of multilaterals and bilaterals including NGOs and national governments.

5.5. The way forward: a Water and Climate Alliance

The development and implementation of adaptation policies and strategies to address the impacts of climate change and increasing variability is a new challenge in the water sector. In recent years, numerous initiatives and activities have started up in the fields of awareness raising, information sharing, network and partnership development, research and methodology development and in implementation support. These support initiatives are very important and will need to continue supporting local water managers in developing countries. There is a need for co-ordination of the initiatives from international down to local level.

The Dialogue on Water and Climate initiated coordination and collaboration among the many stakeholders at global and local level. It encouraged building of alliances among government, NGOs and private sector organisations at the international, regional and national level.

This overall development objective of building alliances and partnerships to encourage adaptation in the water sector will remain important in the coming years. It is proposed that these activities will be continued under a Water and Climate Associate Programme. Objectives of the new Water and Climate Associate Programme (WCAP) of the Global Water Partnership should include:

1) Expanding and strengthening an informed, multi-stakeholder process at basin, national and regional levels that builds the political will to increase the resilience of water management against climate variability and change through a demand stimulation approach and by mainstreaming adaptation into water sector planning.

2) Facilitating the enhancement of capacity and knowledge of water managers by supporting and encouraging sharing of information regarding the vulnerability of the water sector to climate variability and change, including the promotion of assessment methodologies, adaptation mechanisms, and precautionary approaches, by promoting communication between the water, climate and hydrology sectors.

3) Raising awareness of the issues relating to water and climate among stakeholders and decision-makers in the water and climate sectors at the global down to the local level through publications, presentations at national, regional and global conferences and advocacy through the media.

4) Working on the creation of easily accessible funding mechanisms for adaptation in the water sector either through bilateral/multilateral sector funding or through GEF-related funding mechanisms.

Chapter 6: Conclusions and recommendations

6.1 Undeniable evidence

The hydrological cycle is speeding up. That means more frequent and more extreme storms, floods and droughts in many parts of the world. The records show that it is happening already – six major flood disasters in the 1950s, seven in the 1960s, eight in the 1970s, 18 in the 1980s and 26 in the 1990s (see section 1.3.3). We know why it is happening – more of the sun's energy, trapped inside greenhouse gases, evaporates more water, warms the tops of the oceans and the bottom of the atmosphere, melts polar ice, and generally stirs up our weather cauldron (see section 1.5.1).

We can be sure too that it is going to get worse until the effects of global warming have stabilised a long way into the future. Meteorologists can predict with improving accuracy how the climate will change over time in different parts of the world. Using General Circulation Models, they can show how different patterns of human behaviour and socio-economic development in this century ("emission scenarios") would affect temperatures, rainfall and sea levels (see section 1.5.3). The projections confirm how important it is to continue efforts to control emissions of greenhouse gases: depending on the scenario, the average rise in global temperature between 1900 and 2100 will be between 1.4 and 5.8°C and the rise in sea level between 9cm and a massive 88cm.

Mitigation (cutting greenhouse gas emissions) alone is not enough. The problems of climate variability are with us now. Every year, floods kill many thousands of people, make millions homeless and destroy the lives and hopes of millions more. The economic cost is just as devastating: annual losses from hydro-meteorological disasters increased tenfold between the 1950s and the 1990s (see section 1.3.1) including a rise from US$75 billion in the 1980s to more than $300 billion in the 1990s; successive droughts in Kenya in 1997/8 and 1999/2000 are estimated to have cost the country more than 40% of its GDP (see section 4.4.3); and Mozambique suffered a 23% reduction in its GDP after the 1999 floods (see section 1.3.1). It is the poor in the developing world who suffer most. Their fragile livelihoods and precarious homes are the first to go when disaster strikes, while poverty constrains their capacity to protect themselves in advance or to recover afterwards. Repeated disasters set back national economic progress and threaten the achievement of Millennium Development Goals.

6.2 Challenges for water managers

"Climate changes the water rules". The title of this publication highlights the dilemma confronting water managers. They already face formidable challenges in planning for a time around the year 2040 when projected global demand for water will exceed availability (see section 2.1.1). Big fluctuations in seasonal rainfall and inter-annual river flows play havoc with calculations of reservoir operating rules and the amount of storage needed. Historic rainfall and streamflow data cannot be extrapolated without substantial allowances for anticipated trends in climate variability. Analysis of records from 29 of the world's biggest river basins has revealed that 16 out of 21 occurrences of the 100-yr flood were in the second half of the period covered by the data (see section 1.3.1). According to the same analysis, that same 100-yr flood will be as frequent as once every 12.5 years if and when CO_2 levels quadruple in the future (see section 1.5.5). Rainfall extremes like the 428mm in 24 hours that descended on the Japanese city of Nagoya in September 2000 (see Nagoya Dialogue Summary in Chapter 4) overwhelm drainage systems and flood defences designed on the basis of historic data (the previous record daily rainfall in Nagoya was 240mm in 1890).

Coping with natural climate variability is nothing new for water managers. Indeed, some variability is vital to sustain ecosystems, and to maintain soil fertility. It is the intensification of the hydrological cycle and the resulting weather extremes that put both ecosystems and people to the test. They test the water managers too, facing them with peaks and troughs that are off the scale of anticipated seasonal flows. The increasing trend towards integrated water resources management (IWRM) is adding to the managers' armoury, helping them to balance demands from people, industry, agriculture, power and nature with operational needs to moderate the effects of floods and droughts (see Chapter 2). The problems arise in assessing the "factors of safety" that need to be applied to account for future seasonal and inter-annual variability, and the extent to which extreme weather events can be anticipated and prepared for.

Climate prediction and weather forecasting are vital elements in the coping strategies. As well as improving their long-term predictions of climate change on a global and regional basis, meteorologists are getting better at tracking and forecasting extreme weather associated with cyclones and typhoons with reasonable accuracy over periods of a few days or weeks. Increasing understanding of the El Niño phenomenon means that predicting seasonal climate variations for specific regions is also becoming more accurate. An example might be the prediction of lower or higher rainfall in the next planting season in eastern Africa, or more violent storms in the coming monsoon season in southern Asia. What cannot be predicted with certainty is precisely where and when the weather extremes will occur, or just how extreme they will be. That is a vital gap. It creates uncertainty for managers who need to take a view on how to balance the risks of inundation or drought with the costs of protection and precaution. Meanwhile, their consumers, and the communities at risk from the next hydro-meteorological disaster, are voicing their concerns – and their desire to participate in finding the right solutions (see section 4.1).

6.3 Stakeholder partnerships

Although climate is driven largely by global processes, adapting to its extremes means taking action at local and national level. Starting in the first half of 2002, the Dialogue on Water and Climate (DWC) extended support to a total of 18 locally initiated stakeholder "Dialogues" – eight at river basin level, two national and eight regional. As well as bridging the divide between water managers and climatologists, the Dialogues brought together representatives of the community, local government, NGOs and the private sector. Their aim was to assess and prepare responses to the water/climate situation in their own part of the world. The results, summarised dialogue-by-dialogue in Chapter 4, showed the power of partnership and the enthusiasm of community members to participate fully in developing and implementing measures to cope with climate extremes.

All dialogues were driven by their own perceptions on the impacts of climate on the water sector, and their own action agenda. Some (Lena, Aral Sea, Western Africa) sought to verify these perceptions through scientific assessments of their vulnerability to floods or droughts. In others, local perceptions of more frequent and more intense weather events were enough to stimulate initiation of coping plans (Small Valleys, Bangladesh). However, even the most enthusiastic bottom-up partnerships need outside support to help establish early warning systems, or to finance storm shelters, flood defences or the seed and fertiliser for drought-proof crop sowing. Financial support is not unlimited, and both governments and donors like to prioritise. That means comparing the needs of one community for storm-surge protection with those of another for more reservoir storage to combat drought. Measuring vulnerability then becomes an issue.

6.4 Assessing vulnerability to climate extremes

To assess the vulnerability of basins or communities to climate impacts, scenarios are needed which give high resolution of climate parameters in time and space. There are promising operational research developments in spatial and temporal downscaling of the General Circulation Model outputs to basin level. The next step involves integrated assessment models that use climate scenarios from the General Circulation Models (GCMs), but which provide only a coarse top-down methodology for combining "susceptibility" and "adaptive capacity" of countries or geographic regions into proxy indicators of vulnerability (see sections 2.1.1 and 3.2 to 3.6). Helpful as these exercises may be in highlighting global or regional priorities, they cannot home in on the threats and coping capacities in an individual river basin or local community. There are also methodologies being developed for grassroots level vulnerability assessments combining socio-economic and environmental indicators with projected climate threats in a highly focused way (megacities, rural areas, ecosystems, coastal areas, poor neighbourhoods). Section 3.4.1 has an example showing how over the next 30 years Bahrain will start to catch up with the Comoros Islands as the small island most vulnerable to sea level rise. The "Climate Vulnerability Index" used in that exercise has considerable promise, but is still in the development phase, along with other methods being researched by the World Bank, the Red Cross and UNEP/WMO/IPCC (see section 3.1 and agency summaries in Chapter 4).

6.5 Capacity building and financial support

The self-help potential of local agencies is limited by available resources – technical, institutional and financial. Many governments too require significant outside support to implement adaptation strategies for coping with changes in climate. There are three prime reasons why donor governments, relief agencies and other external support agencies should be sympathetic to requests for support (see section 5.1):

1. The polluter pays principle: Greenhouse gases come predominantly from the industrialised countries, but it is primarily the developing countries that suffer the worst impacts.
2. Extreme weather and climate events are having devastating impacts on progress towards the shared developmental goals of poverty alleviation and sustainable development. Precautionary investments in disaster preparedness and adaptation will help to protect developmental progress.
3. Support for local adaptation pays dividends in savings on relief and recovery costs when the extreme event arrives. The Red Cross estimates that each dollar spent on prevention saves from four to ten dollars in relief (see South-East Asia Dialogue summary in Chapter 4).

In international circles, there is a growing consensus on the need to mainstream adaptation to climate variability into the poverty reduction and sustainable development agenda. Adaptation to climate change will soon be fundable through the Global Environmental Facility (GEF), but the limitations on funding through National Adaptation programmes of Action (NAPAs) remain quite restrictive (see section 5.4.3). While the debate goes on about the extent to which adaptation to climate variability is part of coping with climate change, other avenues of support have to be opened up. They will come through the regular dialogues between governments and the international development assistance community and will be hastened by governments committing themselves to mainstreaming adaptation to climate into their national water, poverty reduction and sustainable development programmes.

Numerous international agencies already provide information sharing, capacity building and research support (see section 5.3 and the agency summaries in chapter 5). There is also considerable help and information available for advance warning of extreme weather. Once water managers, climate specialists and support agencies are working in harmony, it is possible to develop effective early warning systems and disaster-preparedness strategies.

The Dialogue on Water and Climate has been successful in bringing together appropriate water-and-climate stakeholders at different levels. What is needed now is the linking of basin-level dialogues with corresponding national and regional ones, to ensure that the local adaptation strategies benefit from the optimum support at higher levels.

6.6 A Water and Climate Alliance

On the basis of lessons learned from the 18 Dialogues, the international organisations that have been the Steering Committee and partners of DWC are committing themselves to continuation of the multi-stakeholder approach and the building of bridges between the climate and water communities. The alliance will continue. It is proposed that an Associate Programme of the Global Water Partnership (GWP) should be the mechanism for supporting the ongoing and new activities. It will have a work programme that includes promoting and facilitating capacity building at all levels, assistance to countries in obtaining technical and financial support for adaptation plans, and continuous advocacy for relaxation of GEF rules to accommodate national adaptation plans that respond to the accelerating hydrological cycle.

6.7 Recommendations for action

The recommended follow-up activities have implications at all levels. They are set out in tabular form alongside, identifying the need for action at basin, country and regional level, and the types of external support needed to make the most of national adaptation strategies.

RATIONALE

DIALOGUES
The 18 dialogues at the national, basin and regional level have shown that bringing together different stakeholders from the government, private sector, NGOs and the information/knowledge sector does stimulate a process to start up awareness raising, information collection and sharing, and preparations for action on the impacts of climate change and increasing climate variability in the water sector.

NATIONAL ADAPTATION PLANS OF ACTION (NAPAs)
The NAPA for LDCs and National Communications for non-LDCs of the UNFCCC, which are eligible for support by the GEF LDC Adaptation Fund provide a useful mechanism for adaptation plans, but GEF support is limited to climate-change impacts and excludes climate-variability impacts. To be relevant to the water sector, the NAPAs should also include adaptation to increasing climate variability.

VULNERABILITY ASSESSMENT
Top-down scenario-based model studies for assessment of national vulnerability to climate change are fairly well developed, relatively easily accessible and frequently used. Grassroots-level tools to assess the vulnerability of particular communities, cities, ecosystems, coastal zones, etc, are still being developed, and are not locally available. These tools are vital to complement the 'top down' assessments and for national/basin/regional planning and priority setting.

PREDICTION AND PREPAREDNESS
Present predictions can provide water managers with reasonably accurate short-term weather information (days up to weeks). Predictions for the longer term (seasons or even a few years) are improving in reliability.

THE CLIMATE AND WATER RESEARCH AGENDA
There is a widely recognised gap in predictive capacity when it comes to forecasting climate at basin level over seasons or years. That is the information needed for water resource planning to cope with climate variability. Temporal and spatial downscaling of predictions from Global Circulation Models is an urgent need. Research is needed on multi-disciplinary tools for integrated assessment f vulnerability on a local scale.

RESEARCH, MONITORING AND KNOWLEDGE SHARING
DWC's Coping Compendium (Chapter 4) highlights a wide range of adaptation options, many still in their infancy in relation to coping with climate variations.
Research and information sharing will accelerate understanding of how to build resilience and moderate the impacts of extreme weather and climate.
The private sector and relief agencies share a common interest in effective protection and preparedness.

CAPACITY DEVELOPMENT
To cope with increasing hydrological variations and weather extremes, water managers need new skills. Climatologists too have to work in different ways to provide the right help to their water colleagues. Both parties can benefit from training, tools development and knowledge sharing, as can the partner agencies involved in the adaptation dialogues

PUBLIC AWARENESS
The 18 dialogues have demonstrated the value of awareness raising to motivate local action.

WATER AND CLIMATE ALLIANCE
The Dialogue on Water and Climate has been an effective networking vehicle to encourage closer collaboration between the climate community (meteorology and hydrology) and the water community. That work needs to continue and expand.

RECOMMENDATIONS FOR FOLLOW-UP

ACTIONS BY COUNTRIES, BASINS AND REGIONS	EXTERNAL SUPPORT
Water managers, in co-operation with national governments, NGOs, etc.) should continue to be encouraged to start multistakeholder dialogues at basin, national and regional level to prepare adaptation plans for climate change/climate variability. The aim should be to link basin dialogues with appropriate country and regional dialogues, to cover the most vulnerable basins and regions	International institutions and agencies are urged to provide technical and logistical support for the activities of new dialogues. Bilateral and multilateral development support agencies can support the operations of the dialogues, where national governments demonstrate that they are integrated with priority developmental objectives. Target: Five new Dialogues per year
Countries (in particular the most vulnerable) should prepare a comprehensive water sector NAPA or National Communication within the overall goals of development and sustainability, following the WEHAB framework as described in the Plan of Implementation of the WSSD and including poverty and vulnerability reduction targets laid down in the Millennium Development goals.	It is recommended that an interagency working group is established under GEF with representatives from multilateral and bilateral agencies including GWP and international NGOs (IUCN, Red Cross) to develop a financial support mechanism for water sector NAPAs for the long term, and also to develop a transitionary financial support facility to support water sector adaptation plan preparation and implementation.
Identify the water sector-related social, economic and environmental vulnerabilities to climate change and extremes through both scenario-based model studies and the best available grassroots vulnerability assessments for specifically vulnerable areas such as coastal areas, marginal lands, cities, small islands, ecosystems, the poor. BUT: take local action without waiting for priority comparisons.	Support is urgently needed for the further development of grassroots-level assessment methodologies like the Climate Vulnerability Index, and their use by regional, country and basin level governmental, science and NGO organisations. International organisations can help with research, co-ordination and finance.
Vulnerable basins or communities should work with best available short term (2-5 days) prediction information and establish early warning systems and response strategies. This may include rehabilitating defunct hydrological monitoring stations and sharing information across international borders. Seasonal prediction and early warning/response systems should be introduced where expected to be feasible and effective.	International river basin authorities/commissions can and should make valuable data on prediction freely and readily available to downstream countries. Technical and financial support from donors/UN agencies can help with early warning systems (from short term to seasonal) and preparedness/response plans.
Work with climatologists, meteorologists and hydrologists in the international specialist agencies to develop best available forecasting and prediction models to suit basin and national needs. Co-operate in pilot testing and data gathering to improve models, and share data across networks of water and climate specialists.	UNESCO, WMO, IRI, Hadley Centre and other international partners have a comprehensive agenda to assist regional and country level water managers with tools for planning purposes that take account of the impacts of climate variability and change on water resources management for people, food, energy and ecosystems. The compendium on coping options should be completed based upon best practices and field level experiences. The compendium should be made available via capacity development activities and on the web.
Research, record and share information on innovative adaptation options. Involve the private sector in micro-credit and risk-sharing initiatives; exchange knowledge internationally on policy instruments, technology, ecological vulnerability/resilience, land-use planning, etc.	WHO, IUCN, WB, UNDP, UNESCO and universities with local partners draw up an agenda for research, methodology development and monitoring systems to study resilience of social, economic, human health and ecosystems to impacts of climate on the water system and the effectiveness of innovative adaptation options. Involve private and non-governmental sectors in risk sharing and innovative financing.
Organise workshops, training courses, distance learning and exchange programmes, to build the capacity of water managers, climatologists and extension workers to address water-and-climate issues. Review institutional frameworks and develop capacity for co-operation in adaptation strategies	UNESCO-IHE, PI, IRI, UN Universities, CAPNET, GWP (tool box) and other capacity development networks further develop, train and apply the tools, including the Coping Compendium, capacitating local level water managers to cope.
Use media, publications, posters and appropriate local communication networks to raise awareness of weather hazards and coping options. Mobilise women's groups, religious leaders and teachers to disseminate key messages	Disseminate publicity materials widely, use internet communications and websites to spread international publicity. Issue timely warnings of impending climatic extremes or El Niño events.
Convert the outcomes of basin, country and regional dialogues into co-operative adaptation strategies and contribute to an expanding global network on water-and-climate issues.	Continue the activities of the DWC through a Water and Climate Associate Programme of the Global Water Partnership, with support from funding agencies. Initiate the proposed Work Programme to support NAPAs and National Communications. Encourage the identified international partners of the WCAP to develop and continue to support programmes and activities on the recommendations above.

Annex 1:

Listing of Dialogues, Thematic Papers and Case Studies conducted in the framework of the Dialogue on Water and Climate

THEMES & DIALOGUES	Science on Water and Climate	Coping and Adaptation	Institutional and Political Aspects	Identifying Critical Regions	Knowledge Transfer
National Dialogues Bangladesh, The Netherlands	√	√	√	√	√
Basin Dialogues San Juan, San Pedro, Thukela, Lena, Murray-Darling, Yellow River, Nagoya, Small Valleys	√	√	√	√	√
Regional Dialogues Aral Sea, South Asia, Central America, Caribbean Islands, Pacific Islands, West Africa, Southern Africa, Mediterranean	√	√	√	√	√
Themes Climate Scenarios and Uncertainties	√	√			
Floods	√	√		√	
Droughts		√			
Sea Level Rise	√	√		√	
Groundwater		√	√	√	
Lakes	√				
Ecosystems	√	√			
Dams and Hydropower	√	√			
Climate Vulnerability Index	√	√		√	
Megacities			√	√	
Health	√	√	√		√
Forecasting Climate Variability	√	√	√		√
Insurance and Financial Sector		√	√	√	
International Conventions and Institutions	√	√	√		
Social and Cultural Aspects in Relation to Coping with Climate Related Disasters		√	√		
Poverty, Water and Climate		√	√		
Philosophies	√		√		
Gender		√	√	√	
North –East Brazil drought forecasting	√		√		√
Venezuela Floods	√	√			√
Food, Water and Climate (ADAPT)	√	√		√	
American Isthmus		√			
Bibliography Water and Climate		√			√
Education and Training Package		√			√
E-Atlas	√				√
Global Analysis Vulnerable Regions	√			√	√

√ = An issue that is considered part of a theme or dialogue

Abbreviations and Acronyms

A

AIACC	Assessments of Impacts and Adaptations to Climate Change
AOGCM	Atmosphere Ocean General Circulation Model

C

CBO	Community Based Organisation
CERUDEB	Centenary Rural Development Bank
COP	Conference of Parties
CVI	Climate Vulnerability Index

D

DWC	Dialogue on Water and Climate

E

EAC	East African Co-operation
ECHAM (4)	GCM of Max Planck Inst. for Meteorology, Hamburg, Germany
ENSO	El Niño-Southern Oscillation
EU	European Union

F

FAO	United Nations Food and Agricultural Organisation
FFWC	Flood Forecasting and Warning Centre (Bangladesh)

G

GBM	Ganges-Brahmaputra-Megha Basin
GCM	General Circulation Model
GCOS	Global Climate Observing System
GDP	Gross Domestic Product
GEF	Global Environmental Facility
GEWEX	Global Energy and Water Cycle Experiment
GHG	Greenhouse Gases

H

HADCMxxGCM	Hadley Institute (version) General Circulation Model
HELP	Hydrology for the Environment, Life and Policy (UNESCO)

I

IAHR	International Association of Hydraulic Engineering Research
IAHS	International Association of Hydrological Sciences
ICZM	Integrated Coastal Zone Management
IGBP	International Geosphere-Biosphere Program (ICSU)
IHDP	International Human Dimensions Program on Global Environmental Change
IPCC	Intergovernmental Panel on Climate Change (WMO/UNEP)
IRI	International Research Institute for Climate Prediction
IUCN	International Union for the Conservation of Nature and Natural Resources
IWRM	Integrated Water Resources Management

L

LDC	Lesser Developed Country

N

NAPA	National Adaptation Programme of Action
NHS	National Hydrological Services
NGO	Non-Governmental Organisation
NOAA	National Oceanic and Atmospheric Administration

O

OECD	Organisation for Economic Co-operation and Development

R

RCM	Regional Climate Model

S

SADC	Southern African Development Community
SAR	IPCC Second Assessment Report
SDR	Department of Rural Development (Nordeste, Brazil)
SEI	Stockholm Environmental Institute
SIDS	Small Island Developing States
SIWI	Stockholm International Water Institute
SLR	Sea Level Rise
SOI	Southern Oscillation Index
SRES	Special Report on Emissions Scenarios (IPCC)
SST	Sea Surface Temperature

T

TAR	IPCC Third Assessment Report

U

UNCED	United Nations Conference on Environment and Development
UNDP	United Nations Development Program
UNESCO	United Nations Educational, Scientific & Cultural Organisation
UNEP	United Nations Environment Program
UNFCCC	United Nations Framework Convention on Climate Change

W

WCRP	World Climate Research Program
WHO	World Health Organization
WHYCOS	World Hydrological Cycle Observing System (WMO)
WMO	World Meteorological Organization
WPI	Water Poverty Index
WSSD	World Summit on Sustainable Development
WTO	World Trade Organisation
WUE	Water Use Efficiency

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