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

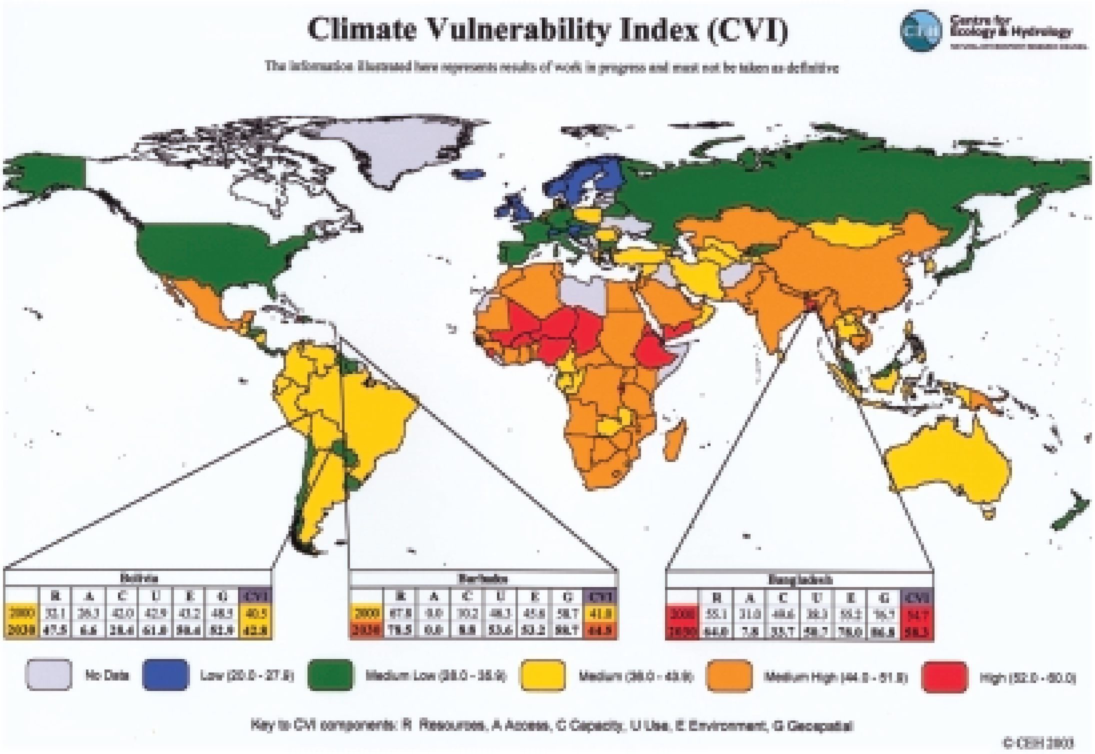


Figure 3.1 *Some preliminary results of applying the Climate Vulnerability Index (CVI) approach to compare vulnerabilities of different regions at present and how it might be affected over 30 years if development follows UNEP's "Policy First" scenario (Sullivan et al, 2003)*

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.

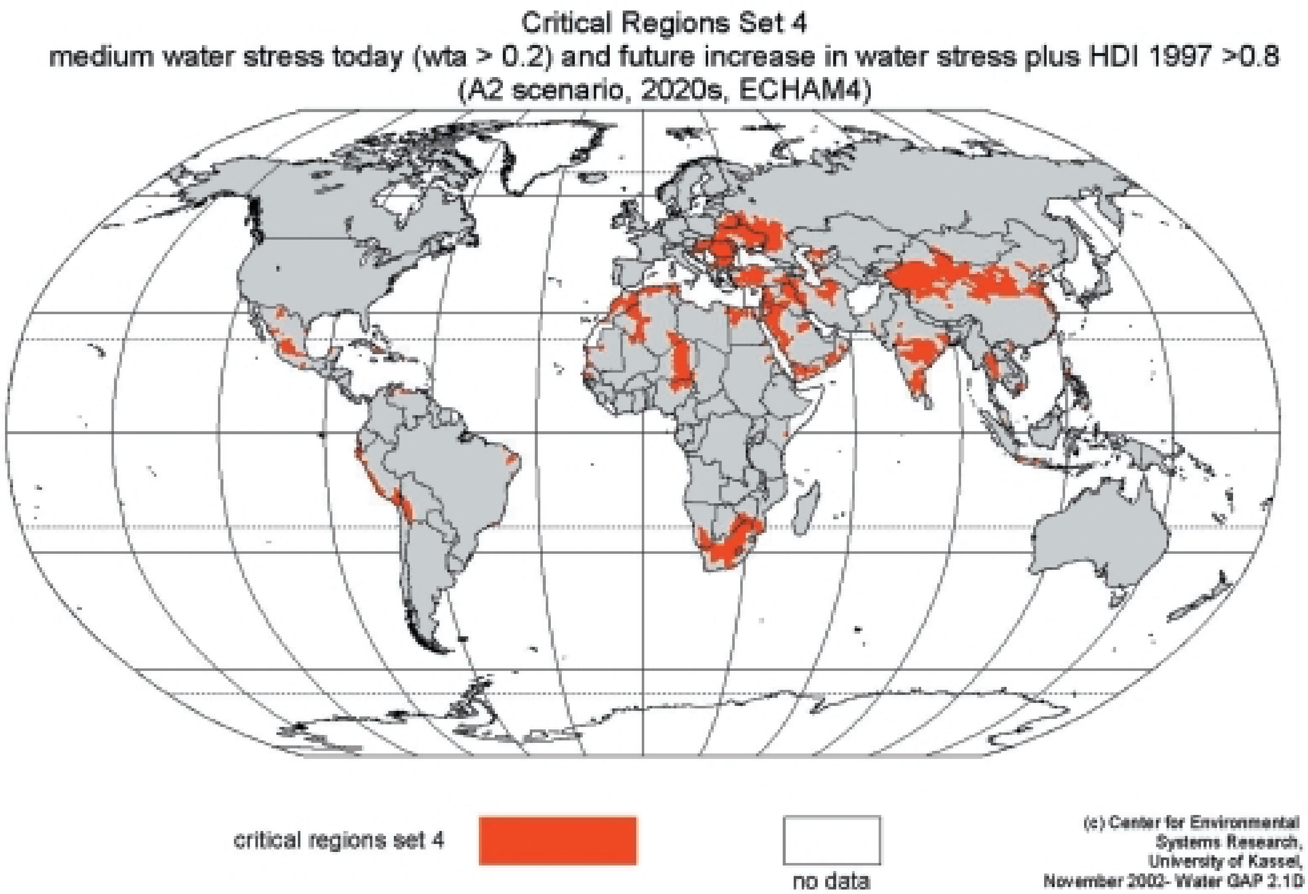


Figure 3.2 *Regions of critical water stress (Alcamo and Heinrich, 2002)*

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

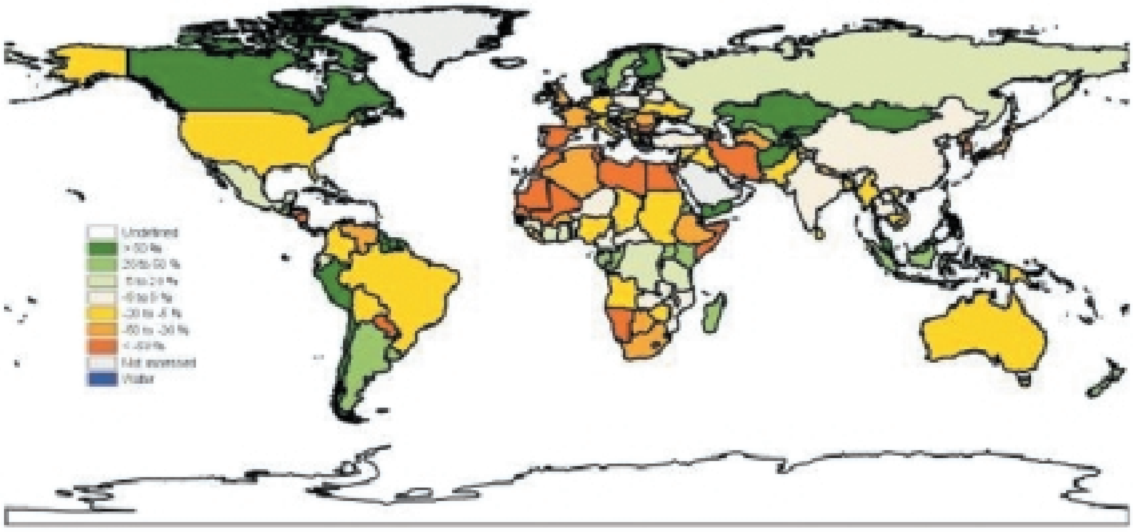


Figure 3.3 *Country-level climate-change impacts on rain-fed cereal-production potential on currently cultivated land (HadCM3- A1FI, 2080s) (Fischer et al, 2002).*

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.

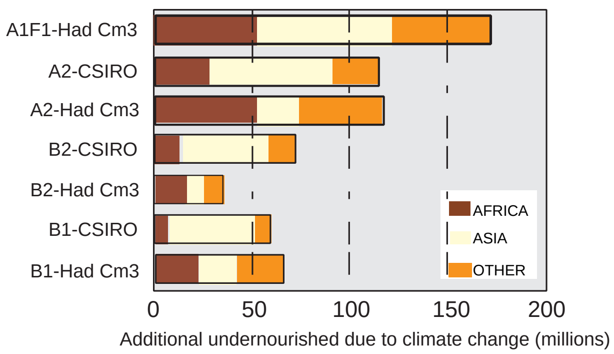


Figure 3.4 *Additional number of undernourished due to climate change, by region, for socio economic conditions of the SRES A2 scenario in the 2080s (Fischer et al, 2002).*

[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.

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.

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)

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

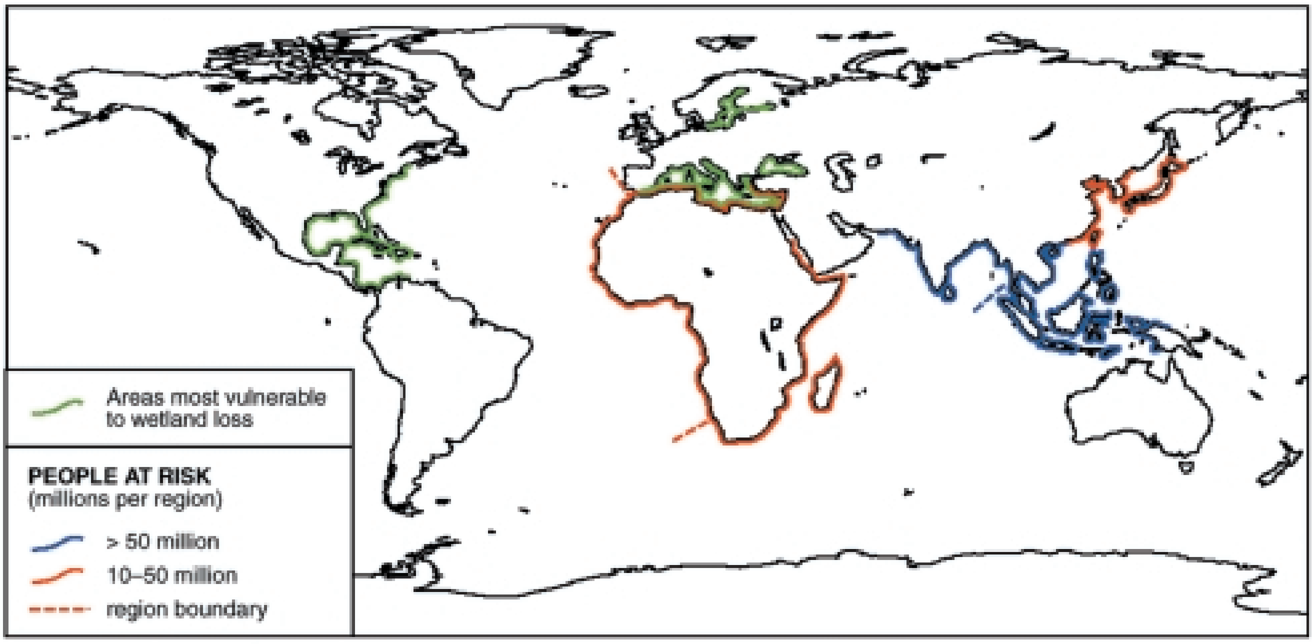


Figure 3.5 *The number of people at risk by the 2080s in coastal regions under the sea-level rise scenario and constant (1990s) protection, showing also the regions where coastal wetlands are most threatened by sea-level rise (Nicholls et al., 1997).*

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

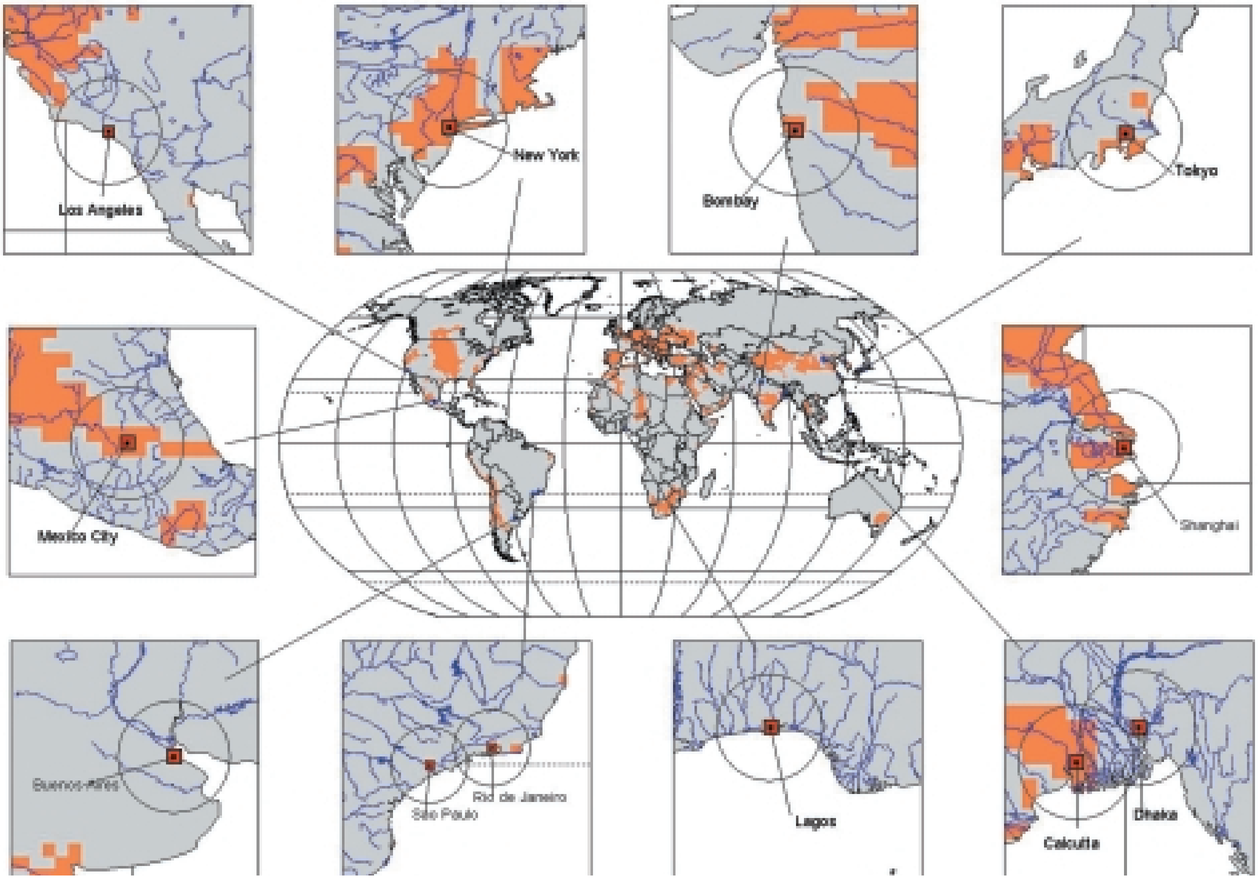


Figure 3.6 *Water stress in regions around selected megacities; current situation (Center for Environmental System Research, University of Kassel, Gemany)*

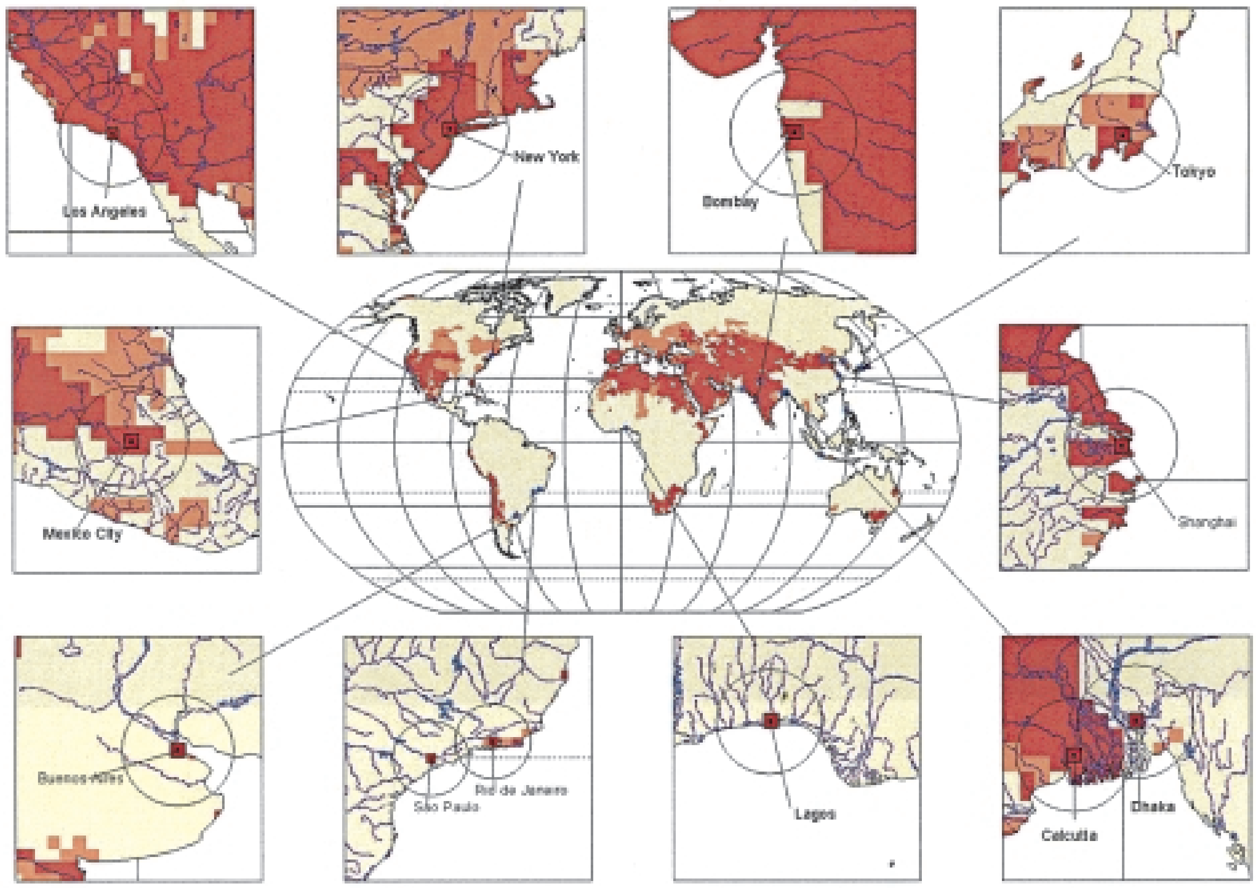


Figure 3.7 *Water stress in regions around selected megacities in the 2020s, under the IPCC A2 scenario, for ECHAM4 climate model in the 2020s SRES A2 (Center for Environmental System Research, University of Kassel, Gemany)*

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.

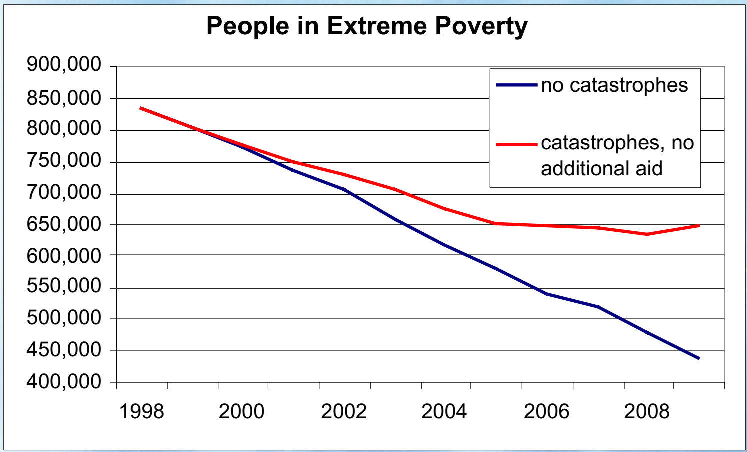
Regardless of whether or not recent changes in climate variability and in the magnitude and frequency of the extreme climate events can be attributed to climate change, an increase in the frequency and intensity of extreme events is being observed (Chapter 1). Evidence suggests that even small changes 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.