Chapter IV
Reducing human harm from natural hazards

Summary

- The frequency of natural disasters, especially in the form of floods and storms, has quintupled over the past 40 years, the elevated disaster risk being partly due to the effects of climate change. Developing countries bear a higher share of the adverse consequences of that increased risk.
- Heightened disaster risk associated with poor management of the natural environment and human-induced climate change requires a long-term approach to reducing risk from natural events. An integrated and preventive framework embedded in national development strategies would be most effective.
- Existing technologies and knowledge systems—including those embodied in traditional and indigenous knowledge—are up to the tasks of reducing disaster risk and adapting to climate change. The bottleneck in their application to the local context lies in the cost of adaptation and investment, given other competing public priorities. To ensure that disaster risk management is accorded the appropriate attention, disaster reduction and adaptation programmes must be an integral part of national development strategies.

Introduction

In the 1970s, about 69 natural disasters were recorded worldwide every year. By the 2000s, this average had increased to 350 per year. Changes in the natural environment, owing in part to global warming, have elevated disaster risk and in consequence adaptation to those changes is testing human ingenuity. Developing countries tend to bear a disproportionate share of the adverse consequences of increased disaster risk since multiple vulnerabilities associated with lower levels of development and inadequate resources hinder them from more rapidly building up resilient infrastructure and knowledge capacities for risk reduction.

Vulnerability to disaster is highly correlated with the level of development and the incidence of poverty

Susceptibility to harm is highly correlated with inequities in respect of the level of development and the incidence of poverty. Overcoming those challenges within an environmentally constrained world means that technological transformation for green growth must be swift and inclusive. The uncertain availability of key inputs for economic growth and life survival such as renewable energy and water makes the utilization of technologies for disaster risk reduction and sustainable development more urgent. Putting an end to these inequities will require the inclusion of the appropriate technological content in the adaptation strategies and livelihood sphere of those who are poor and most vulnerable.

The present chapter assesses strategic options for facilitating and realizing the technological transformation needed to adapt to and reduce disaster risk, and to create the domestic capacity to respond swiftly and effectively to the increased adverse impacts of natural hazards on livelihoods and the likelihood of catastrophic events.

Multidimensional impacts of natural disasters

The number of natural disasters has quintupled over the past 40 years

As noted above, the number of natural disasters has quintupled over the past 40 years. Figure IV.1 depicts this trend for floods, storms, droughts, extreme temperatures, earthquakes, volcanoes, slides and wildfires. By far most of the increase can be accounted for by the greater incidence of hydro-meteorological disasters (floods, storms, droughts and extreme temperatures), which are associated with climate change. Further, the number of prolonged droughts has tripled.

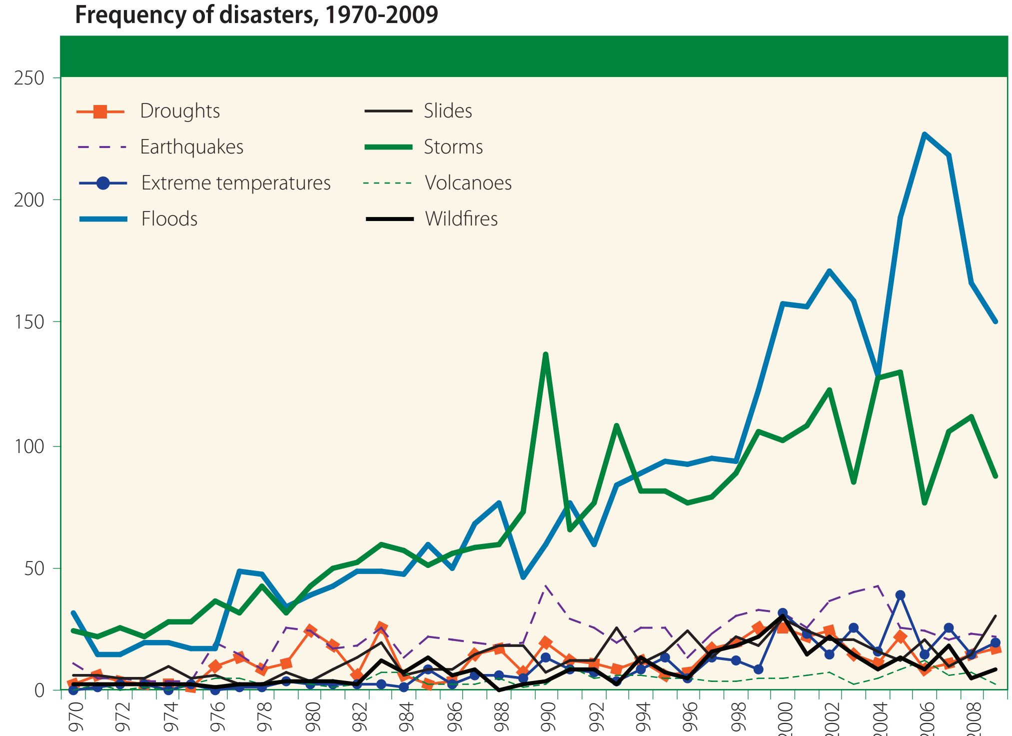
The *World Economic and Social Survey 2008* (United Nations, 2008b, p. 81) stressed that, although geologic disasters can inflict severe damage, hydro-meteorological disasters "pose a greater threat of becoming large-scale (catastrophic) disasters and also account for much of the rising trend of reported disasters in recent decades".

In many countries and regions, the weather has become more erratic and often there have been spells of extreme temperatures. Some areas have been hit by much more intense rainfall in recent decades, while others have seen their dry seasons turn into prolonged droughts. Many countries regularly encounter both manifestations of these forces of nature: heavy storms and rainfall, and severe droughts.

The increased frequency of weather-related events is exacerbated by their increased intensity

The increased frequency of hydro-meteorological hazards is exacerbated by the increased intensity of these events. While the number of category 1 hurricanes and storms

Figure IV.1
Frequency of disasters, 1970-2009



Source: UN/DESA, based on data from the Centre for Research on the Epidemiology of Disasters (CRED) International Disaster Database (EM-DAT), Université catholique de Louvain, Brussels, 2009. Available from www.emdat.net.

remained approximately constant throughout the 35-year period 1970-2004, hurricanes and storms in the strongest categories (4 and 5) have almost doubled in number in all ocean basins (Webster and others, 2005). The number of droughts that lasted from one to two years or longer tripled between 1970-1979 and 2000-2009.

Mapping disaster risks

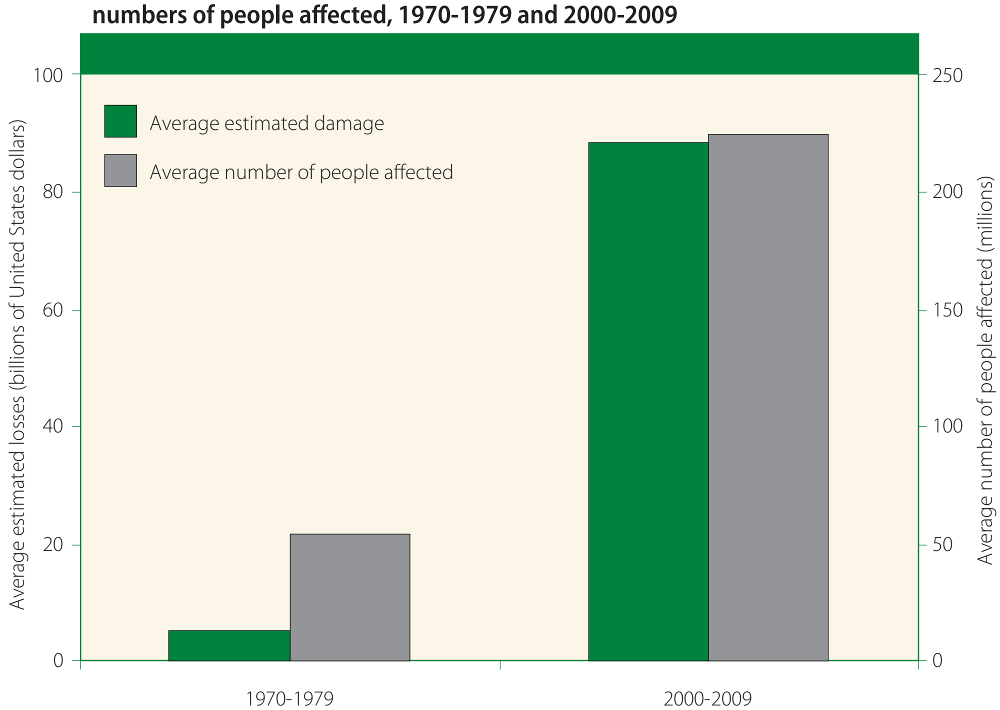
Disasters are becoming more damaging to livelihoods

There has been a long-term declining trend in the average number of persons killed per disaster, leaving the average number of deaths per year from disasters more or less constant. At the same time, however, the increased frequency of natural disasters has contributed to a large increase in the number of persons affected by disasters and in the estimated costs of the damages incurred (figure IV.2). Damages have averaged $88 billion per year since 2000, compared with an average of $12 billion in the 1970s. While disasters have become less life-threatening, they have become more damaging to the livelihoods and well-being of the communities hit.

The human impact of disasters is significantly higher in developing countries

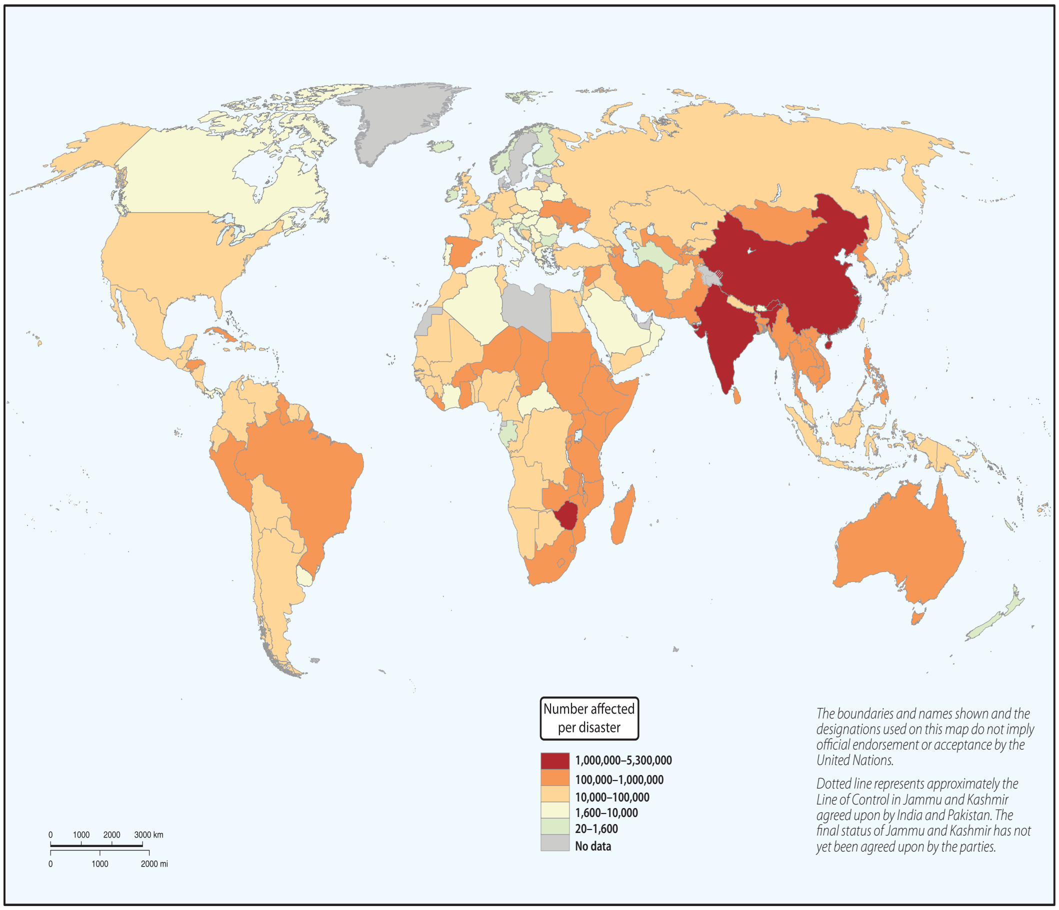
The human cost measured in terms of both the number of persons affected and the loss of human lives is significantly higher in developing countries, albeit with regional differences. According to figure IV.3, which shows the greater vulnerability of the populations of developing countries, the number of affected people (injured and homeless) is highest in developing Asia, although large parts of Africa and Latin America also show high degrees of impact. The forces of nature have also affected large numbers of persons per event in developed countries (most notably Australia and Spain), despite their generally greater resilience.

Figure IV.2
Estimated damages caused by natural disasters and numbers of people affected, 1970-1979 and 2000-2009



Source: UN/DESA, based on data from the Centre for Research on the Epidemiology of Disasters (CRED) International Disaster Database (EM-DAT), Université catholique de Louvain, Brussels, 2009. Available from www.emdat.net.

Figure IV.3
Number of persons affected per disaster,[a] by country, 1990-2009



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Source: UN/DESA, based on data from the Centre for Research on the Epidemiology of Disasters (CRED) International Disaster Database (EM-DAT), Université catholique de Louvain, Brussels, 2009. Available from www.emdat.net.

Note: Grey areas represent countries where there was no disaster incidence, where data were not available or where there were no persons affected by disaster(s).

a Including floods, storms, droughts, extreme temperatures, earthquakes, volcanoes, slides and wildfires.

Most disasters have occurred in developing regions

While all regions are exposed to natural hazards, it is in developing regions that most disasters (comprising droughts, earthquakes, extreme temperatures, floods, slides, storms, volcanoes and wildfires) tend to occur (table IV.1). Also, by far most deaths, injuries and cases of homelessness (over 95 per cent) result from natural disasters in developing regions. The average number of persons killed per 100,000 inhabitants is five times higher in developing than in developed regions. Although the divergence between developing and developed regions continues when considering least developed countries and the group of small island developing States, the proportions vary. The number killed per 100,000 in least developed countries is 12 times higher than in developed regions and in small island developing States, more than 2½ times higher. Further, the number affected per 100,000 in least developed countries is 16 times higher than in developed regions and in small island developing States, about 10 times higher. The fact that the incidence of affected persons is somewhat below the developing-country average can be explained by the fact that many least developed countries and small island developing States tend to be less densely populated. Australia and New Zealand are exceptions owing to the higher incidence of climatic events in those countries, which have been affected by extreme temperatures, storms and floods, droughts and wildfires, as well as earthquakes, over the last 20 years.

Table IV.1
Frequency of natural disasters and impact by regions, 1970-2009

	Number of disasters	*Killed (thousands)*	*Affected (millions)*	*Killed (per 100,000)*	*Affected (per 100,000)*
Developing regions	**6 482**	**2 788**	**5 966**	**68**	**145 182**
Africa	1 200	705	370	109	56 982
Asia (excluding Japan)	3 478	1 828	5 401	61	179 051
Latin America and the Caribbean	1 575	250	191	57	43 717
Oceania	229	4	4	68	59 101
Developed regions	**2 451**	**153**	**84**	**14**	**7 364**
Australia and New Zealand	238	1	16	6	78 216
Europe	1 281	127	37	18	5 251
Japan	180	10	4	8	3 100
Northern America	752	15	27	5	9 356
Total	**8 933**	**2 941**	**6 049**	**56**	**115 361**
Memorandum items:					
Least developed countries	1 363	981	631	189	121 471
Small island developing States	636	18	35	37	72 760

Source: UN/DESA, based on data from the Centre for Research on the Epidemiology of Disasters (CRED) International Disaster Database (EM-DAT), Université catholique de Louvain, Brussels, 2009. Available from www.emdat.net.

Is climate change to blame?

The number of disasters that are climate-related has grown at an accelerating rate.

The number of climate-related disasters has grown at an accelerating rate since the 1950s, while geophysical disasters have followed a relatively stable upward trend, as was shown in figure IV.1. As this suggests the existence of a driver of increasing climate-related disaster events, researchers have tried through complex models to quantify to what extent weather shocks are related to climate change. The Intergovernmental Panel on Climate Change (IPCC) (2007a) warns, however, that results are often not conclusive, since climate models are constantly being updated and improved. The model-based analyses available to date suggest that climate change will result in warmer or fewer cold nights, warmer days and more occurrences of hot days over most land areas. The number of spells of warm weather and heatwaves, as well as the frequency and duration of droughts, will likely increase. This will result in decreased agricultural yields in most warm areas, where the majority of developing countries are located, and will have adverse effects on the availability and quality of groundwater. Climate change will also increase the frequency of heavy precipitation in most areas as well as the number of intense tropical cyclones in areas where they are at present occurring. Using model simulations, it has been estimated that each rise in tropical sea surface temperature by 1° C will increase the speed of hurricane surface winds by between 1 and 8 per cent and the degree of core rainfall by between 6 and 18 per cent (United States Climate Change Science Program, 2008).

Disaster-proofing can offer an opportunity to build infrastructure that utilizes more advanced technology

For many developing countries, environmental constraints and shocks are already part of a vicious cycle, which keep them trapped at a low level of income, undermines their resource base and restricts their ability to protect themselves from future shocks (United Nations, 2008b; 2009). While developing countries will need to take these adverse effects into account, they can also respond to them as offering an opportunity to make changes in living arrangements, build infrastructure that can absorb labour, and use more advanced technology for adaptation to and reduction of disaster risk.

Unequal impacts on livelihoods

Settlements of low-income people are often the most vulnerable

Developing regions bear the brunt of the adverse impacts of natural hazards (United Nations, 2008b; 2009). Droughts in sub-Saharan Africa and flooding in parts of Asia have already ravaged thousands of livelihoods, while heat spells have increased the risk of water scarcity in some countries. Also, urban development tends to increase environmental pressures that lead to disasters such as flooding, and settlements of low-income people are often the most vulnerable in this regard. Affluent groups—whether in developing countries or not—are often in a better position to withstand flooding, as the experience of the 2005 hurricane Katrina in New Orleans demonstrates (McGranahan, Balk and Anderson, 2007).

Unchecked climate change threatens to reduce agricultural yields and increase the number of malnourished children by 2050

Climate change has been associated with shifted growing seasons, threatened water sources and exacerbated food shortages. Unchecked climate change would reduce agricultural yields which, according to one estimate, could in turn cause a 20 per cent increase in the number of malnourished children by 2050 (Food and Agriculture Organization of the United Nations, 2009b). The adverse impacts on food production and nutrition would have ripple effects directly affecting the employment, income and livelihoods of both poor small farmers and urban-dwellers. In Bangladesh, for instance, the overflow of seawater has affected the livelihoods of fishermen, since rivers are now contaminated and fish banks have been decimated. By 2050, 70 million people in Bangladesh could be affected annually by climate change.

A greater frequency of extreme temperatures will have devastating consequences

The impacts of the symptoms of climate change have different dimensions. A greater frequency of extreme temperatures, for example, can have devastating consequences. In the summer of 2010, the Russian Federation faced the worst heatwave in its history, which caused 56,000 fatalities and left 100,000 homeless and over 500,000 hectares of forests destroyed by fires. In general, longer and drier seasons in Argentina, Canada, the Russian Federation, Ukraine and the United States of America have severely damaged harvests.

Similarly, the range of health risks from climate change and natural disasters is likely to be considerable, with all parts of the globe affected, as the unprecedented number of deaths in Europe from recent heatwaves has demonstrated. However, health vulnerability is very closely linked to other vulnerabilities, with the burden of climate-sensitive diseases imposed overwhelmingly on the poorest populations which also experienced the lowest coverage by health services. In fact, the people most vulnerable to climate change are those who have not been well protected by health sector interventions in the past. Meanwhile, it is not variation in the extent of climate change but in the magnitude of pre-existing health problems that has had the greatest influence on impacts in different regions. A recent assessment by the World Health Organization (WHO) (2009) estimates that the burden of disease imposed through the modest warming that has occurred since the 1970s is causing about 150,000 additional deaths annually in low-income countries from four climate-sensitive health outcomes—malnutrition, diarrhoeal disease and malaria. These additional deaths are concentrated in already vulnerable population groups; for instance, 90 per cent of the burden of malaria and diarrhoea, and almost all of the burden of diseases associated with undernutrition, are borne by children aged 5 years or under (Campbell-Lendrum, 2009; United Nations, 2009). Over the long term, higher temperatures will induce excessive levels of ozone and other air pollutants that provoke cardiovascular and respiratory diseases, and of pollen and other aero-allergens that trigger asthma, with the poor and the elderly being hardest hit (Beggs, 2004).

As many of the most important infectious diseases are highly sensitive to both temperature and precipitation conditions, higher temperatures will increase the rates of survival and replication of bacterial contaminants of food and water sources, which are responsible for imposing a large proportion of the burden of diarrhoeal disease, particularly in poor countries. Already, per capita mortality rates from vector-borne diseases are almost 300 times greater in developing regions than in developed ones (World Health Organization, 2009). The situation creates a double burden for women, who can be discriminated against based on their diseases-related afflictions (United Nations Children's Fund, 2008; UN Women Watch, 2011).

Per capita mortality rates from vector-borne diseases are almost 300 times greater in developing regions than in developed ones

Flooding may pose additional risks to human health. In Bangladesh, where arsenic contamination of groundwater is heavy, flooding increases the rate of exposure among rural populations. Long-term exposure to arsenic has deleterious health effects, including the increased incidence of certain cancers.

The most immediate effect of hydro-meteorological hazards on health and well-being is likely to be a function of the availability of water. It is estimated that one quarter of the population in Africa (about 200 million people) experience water stress (Ludi, 2009). Increasing temperatures and more variable precipitation are expected to reduce the availability of freshwater, making it more difficult to fulfil basic needs for drinking, cooking and washing. Meanwhile, a greater incidence of flooding, stemming, inter alia, from more intense precipitation and from sea-level rise in lower coastal zones, will further contaminate freshwater supplies, thereby further increasing water scarcity.

The most immediate effect of weather-induced hazards on health and well-being would be a function of the availability of water

The presence of large human populations in those zones has further increased the vulnerability of the coastal ecosystems. Two thirds of all cities worldwide with a population of more than 5 million are located within coastal areas with an elevation of less than 10 metres. Because of growing urban development and increased extraction of groundwater, among other factors, land has sunk in some places. The territory around Tianjin in China, for example, has been sinking at the rate of about five centimetres per year. In cities located in large river deltas, land areas have been disappearing because of sediment deposition. In the absence of added protection, lower land levels enhance the vulnerability to more frequent flooding, coastal erosion and the immersion of salt in groundwater.

Lower land levels increase vulnerability to more frequent flooding and coastal erosion

Natural hazards will thus have varying impacts on communities depending on the nature of the hazard and the location, resilience of infrastructure and preparedness of the population in affected areas. Table IV.2 summarizes some of the possible effects of increased climate-related natural disaster risks.

Enhanced risk of "extreme" disruptions?

Recent research confirms that major disruptions in the ecosystem, often referred to as "extreme events", have become more likely. Such events could already be occurring in the area of biodiversity (as evidenced by rapid extinction of species) and may be close to affecting fisheries and some water systems (Rockström and others, 2009).

The increased likelihood of extreme events led major stakeholders to reassess current climate change adaptation strategies through the preparation of a special report on the theme (Intergovernmental Panel on Climate Change, 2009). It is argued therein that "gradual and non-linear change to ecosystems and natural resources and increasing vulnerability further increases the consequences of extreme weather events" (p. 2). At the current global average temperature, the likelihood of extreme events has increased,

The likelihood of extreme events has increased

Table IV.2
Multiple potential impacts of changing climate conditions

Enhanced natural hazard risk	*Potential impacts*
Higher variability in local climate	• Major increase of hours lost due to extreme events
Sea-level rise	• Loss of coastal land • Problems in water supply and drainage systems • Increased risk of flood damages
More intensive droughts	• Increased water demand during hot, dry summers • Higher risk of fires, particularly in informal settlements • Increased risk of new vector-borne and water-borne diseases or changes in their spatial distribution
Increase in frequency and magnitude of flooding	• Disruption of the transport system • Increased risk of new vector-borne and water-borne diseases or changes in their spatial distribution • Major increase of hours and trips lost due to extreme events
Heatwaves	• Increased mortality and health risk due to the combination of heat and air pollution • Problems of energy supply • Increased water demand
Increased occurrence of storms and storm surges	• Increased risk of flooding • Possible contribution of storms and floods owing to the combination of extreme events to blockages of drainage systems

Source: Adapted from Birkmann and others (2010a).

and the threat of large-scale discontinuities such as "changes in the ocean conveyor-belt heat-distribution system or catastrophic thawing of the Arctic leading to massive releases of methane" grows if global warming leads to an average temperature rise of more than 2° C above pre-industrial levels. In particular, the risks of large sea-level rise and extreme weather events are currently larger than previously thought (World Bank, 2010a).

Extreme events are more likely to be cross-border

Extreme events are more likely to be cross-border, with serious damage being inflicted on different sectors of the economies affected. The 2004 tsunami in Asia and 2011 earthquake in Japan are recent reminders that the damages and losses resulting from disasters can be staggering, if the location and the existing level of resilience of the social and economic infrastructures renders the areas affected particularly vulnerable. Total damages and losses incurred by Indonesia were more pronounced in the social sector (health, education and housing), while in Sri Lanka it was the productive sectors (fisheries, industry and commerce, tourism and agriculture) that suffered more (Birkmann and others, 2010b).

There are uncertainties associated with predictions of possible disaster scenarios, which are often coloured by their own assumptions about future weather, degrees of global warming and tipping points (Gillett and others, 2011). In cases where the causes of the increasing risk of large disasters and catastrophes are sufficiently understood, shifts in individual and social behaviour and application of known technologies to reduce their impact are urgent.

Approaches to disaster risk reduction and climate change adaptation

Existing incremental approaches

Fragmented actions could, at worst, cause new problems or aggravate existing ones…

Despite imminent threats, disaster risk management and adaptation to climate change in developed and developing countries alike have not been mainstreamed into broader decision-making processes (Adger and others, 2003; Huq and Reid, 2004). The challenge tends to be addressed by adding an "extra layer" to existing policy design and implementation mechanisms rather than by adjusting the original design so as to confront climate change in a more integrated way (O'Brien and others, 2008). Equating adaptation measures with emergency relief and placing the challenge within a framework of reliance on requests for donor support (a frequent approach) has not helped, having in fact given rise to an often bifurcated outlook, based on which efforts either focus on responses to the impacts of climate change (through coping measures) or seek to reduce exposure through climate-proofing existing projects and activities, particularly in the context of disaster risk management. While these two approaches share a common goal, there is a real danger that the perspectives underlying coping and proofing pull in different policy directions and that fragmented actions will end up, at best, creating a partial solution to problems and, at worst, causing new problems or aggravating existing ones (Sanchez-Rodriguez, Fragkias and Solecki, 2008).

…including a number of closely interlinked and compounding threats to social and economic security

As discussed in *World Economic and Social Surveys 2008* and *2009* (United Nations, 2008b; 2009), there is indeed a real danger, already apparent in the response to natural disasters, that underlying structural causes of vulnerability and maladaptation will be ignored, including a number of closely interlinked and compounding threats to social and economic security.

Recent efforts to forge a more consistent approach to the adaptation challenge and weather shocks stress the central role of market incentives (Organization for Economic Cooperation and Development, 2008). These efforts usefully highlight the methodological challenge inherent in evaluating the costs and benefits of disaster risk reduction and adaptation to climate change, point to a role for positive incentives, and help expand the scope for more efficient coping and risk-reduction strategies.

However, such an approach tends to perceive the challenge in terms of a series of discrete and unconnected threats which can be addressed through incremental improvements made to existing arrangements, thereby ignoring the large-scale investments and integrated policy efforts that are likely to be called for in response to climate-related threats.

The need for an integrated approach

The alternative approach perceives adaptation in terms of building resilience with respect to climatic shocks and hazards by realizing higher levels of socio-economic development so as to provide threatened communities and countries with the requisite social and economic buffers. As elaborated in *World Economic and Social Surveys 2008* and *2009* (United Nations, 2008b; 2009), such an approach would contribute to meeting the larger development challenge of overcoming a series of interrelated socio-economic vulnerabilities.

The Hyogo Framework for Action supports the integration of climate change adaptation and disaster risk reduction into national development strategies

Disaster risk reduction strategies are now moving increasingly in this direction. Until 2005, those strategies had dealt with the adverse effects of natural hazards without explicitly recognizing the impact of climate change. Nevertheless, this experience allowed the accumulation of invaluable knowledge on how to cope with and reduce the adverse impact of disasters. As noted above, for most countries and at different income levels, a significant reduction of fatalities per disaster has been observed during the last two decades. However, the increased incidence of climatic disasters, that is, those linked to hydro-meteorological hazards, has required a reconsideration of disaster risk reduction strategies. Within the Hyogo Framework for Action 2005-2015: Building the Resilience of Nations and Communities to Disasters,[1] 168 Governments agreed to integrate climate change adaptation and disaster risk reduction by: (a) identifying climate-related disaster risks; (b) designing specific risk reduction measures; and (c) improving the use of climate risk information (para. 19 (c)). This approach focuses on responding effectively to more frequent and intense hydro-meteorological hazards and on the need to mainstream risk reduction into national development strategies.

A significant strain in the thinking on disaster risk reduction was focused on policy responses to volcanic eruptions, tsunamis and earthquakes. Climate change adaptation strategies, on the other hand, focus on increased resilience to hydro-meteorological hazards, with emphasis on finding a sustainable and preventive approach to disaster risk reduction. With greater consideration given to climatic hazards caused by human activity, disaster risk reduction strategies are becoming more long-term in perspective and more oriented towards prevention of disasters through investing in sustainable development.

Risk, uncertainty and catastrophes

In economics a key distinction is made between the concept of risk and that of uncertainty. In the present context, risk would apply to a situation where the probability and impact of an adverse event "can be inferred from past behaviour of the economy and the ecosystem" (Ocampo, 2011b, p. 19). Risk would then apply to a situation involving the likelihood of damages caused by hurricanes and tropical storms in certain parts of the world. Because the expected costs of such risks are quantifiable to a certain degree, resources can be set aside to insure against the potential damage.

Even where risks can be quantified, the impact of interactions among these risks could be uncertain

Uncertainty is a condition in which the probability and scale of adverse events cannot be inferred from past information. The uncertainty can arise with respect to the category of "known unknowns"; in this instance, awareness can exist concerning the possibility of a catastrophic event, such as a natural disaster, but with few clues regarding whether such a disaster could set in motion irreversible processes beyond certain thresholds. This form of uncertainty is incorporated, for instance, in some future climate change scenarios. Yet, even where risks can be quantified, the impact of interactions among these risks could be uncertain. In this regard, Rockström and others (2010) suggest that one type of uncertainty stems from "what human-induced surprises could be triggered, even though several of the risks have been identified [such as the] abrupt change in the African and Indian monsoons, accelerated melting of glaciers, abrupt savannization of rainforests [and the observed] abrupt collapse of the Arctic summer ice in 2007" (p. 34).

When the issue is one of risk, in particular in matters of diseases and other health challenges, it is incumbent on societies to invest in and set aside resources substantial enough to deal with the calculated impact of disasters and other threats to human

1 A/CONF.206/6 and Corr.1, chap. I, resolution 2.

life. When the risk and its distribution across the population can be calculated actuarially, private insurance could be utilized to raise the needed resources. Even when risks are well quantified, an adequate level of public investment is required to induce private investor participation, in, for example, general public health and seasonal flood control. When the existing domestic technology is not adequate for dealing with those risks, public authorities can either import it or invest in its development. Cost-benefit calculations can provide guidance on the level of public funding required, suitable financing modalities, and the manner in which risks are to be incorporated in national development strategies.

Detailed studies on the likelihood and potential costs of selected hazards would be advisable

However, when the threat belongs to the category of uncertain events, guidance will be limited on probability of impact and scale of the threat. The potential cost of extreme events raises the question how much a country can accomplish through preventive strategies and building resilience. Nevertheless, incorporating those threats in national planning is appropriate. Undertaking detailed studies on the likelihood of extreme events and the potential costs for selected hazards might also be considered by national authorities. The ferocity of onslaught of some recent natural hazards suggests that uncertainty in connection with natural events is quite pervasive and that building climate-proof infrastructure would not eliminate all risk.

Given the likelihood of extreme events, three sets of critical questions need to be posed when addressing the investment and technological challenges of providing protection:

- What kind of infrastructure would be resilient and how much should be invested in such infrastructure? Should precautions be taken to eliminate even the smallest possibility of a ruinous catastrophe? How should the costs and benefits of the necessary investments for present and future generations be weighed? In some cases, a more pointed question could be asked, namely, whether providing greater resilience is feasible at all in the case, for example, of some small island developing States and hence whether other "adaptation strategies" might be needed, such as massive evacuation of threatened populations;
- What kinds of research and development need to be promoted to achieve better protection against natural disasters, through the devising of better technological solutions in the area of climate-proofing of infrastructure and better management of the natural environment?
- How could these considerations be aligned with broader national sustainable development strategies and global disaster reduction strategies?

The road to technological transformation

Societies seeking to achieve the overall objective of reducing the impact of disaster risk are confronted with difficult choices as regards investment and technology policy. Because resources are finite, the coverage of disaster reduction is necessarily finite. The fact that the geographical context, the historical record in respect of disasters and projected climate change impacts vary from country to country implies that the nature and the scale of extreme events will vary from country to country as well. Strategy choices will be more limited in countries like the small island developing States that are more vulnerable to extreme events. Countries, operating within their limits, will eventually call on other countries for assistance when the scale of an actual disaster overwhelms domestic resources that can be devoted to disaster response and prevention.

While there are no general strategies for confronting these issues, national development strategies can identify explicitly the natural hazards that impose risks on projected development results and, on that basis, establish a prioritization of risks that must be addressed by investment and technology development programmes. National Governments can also identify the natural hazards that are regional in nature and then undertake to facilitate regional investment strategies.

Harnessing local technologies

For many poor countries, the strategic challenge is to combine the best local knowledge on adaptation with advanced expertise

For many poor countries, the strategic challenge is to combine the best local knowledge on adaptation with the expertise of qualified professionals and practitioners. The United Nations Framework Convention on Climate Change (2006) underlines that "(m)ost methods of adaptation involve some form of technology—which in the broadest sense includes not just materials or equipment but also diverse forms of knowledge" (preface). The Cancun Adaptation Framework (United Nations Framework Convention on Climate Change, 2011, decision 1/CP.16, sect. II) stresses that adaptation "should be based on and guided by the best available science and, as appropriate, traditional and indigenous knowledge, with a view to integrating adaptation into relevant social, economic and environmental policies and actions" (para. 12).

Through use of local knowledge, some communities have been able to cope with floods by building houses on stilts and cultivating floating vegetable plots, while remote satellite sensing has been able to provide more accurate weather forecasts for flood prevention. Such local action is vital. The visionary project of green integrated urban planning in Curitiba (Brazil) created a balance between promoting green economic growth and building resilience to more intense and frequent natural hazards, including floods, extreme temperatures and population density, and developing green areas (box IV.1). In Ho Chi Minh City (Viet Nam), where communities have been involved in mangrove rehabilitation, local action has been essential for effective adaptation (see below and annex IV.1).

Box IV.1

Smart and integrated urban planning in Curitiba, Brazil

While the population of Curitiba grew from 361,000 in 1960 to 1,828,000 in 2008, it did not experience the typical concomitants of expansion, namely, congestion, pollution and reduction of public space. For instance, the city's green area expanded from 1 square kilometre to over 50 square kilometres per person between 1970 and 2008, despite the fact that its population density increased threefold in the same period.

One of the key choices of urban planning had been growth in a "radial linear-branching pattern", which served to enhance green areas and encouraged, through a combination of land-use zoning and provision of public transport infrastructure, the diversion of traffic away from the city centre, the development of climate-resilient housing, and the location of services and industries along the radial axes.

By turning areas vulnerable to flooding into parks and creating artificial lakes to hold floodwaters, Curitiba has managed to address its potentially costly flooding problem. The cost of this strategy, including the relocation costs of slum-dwellers, is estimated to be five times less than that of building concrete canals. Among other results the property values of neighbouring areas appreciated and tax revenues increased.

Curitiba has also promoted waste management infrastructure and public awareness on waste separation and recycling. With 70 per cent of the city's residents actively recycling, 13 per cent of solid waste is recycled in Curitiba, compared with only 1 per cent in São Paulo.

Source: United Nations Environment Programme (2010a); and Rabinovitch (1992).

Institutional gaps

The Cancun Adaptation Framework reaffirmed the institutional focus by stressing that "adaptation … requires appropriate institutional arrangements to enhance adaptation action and support" (para. 2 (b)). One dimension of such arrangements would be the mainstreaming by Governments of investments in disaster risk reduction research and education into science, technology and production sector policies, thereby making them part of green national innovation systems, as discussed further in chapter V.

Societies also have to overcome political resistance to deployment of technologies on location. Harnessing the energies of different stakeholders with diverse interests during the process of creating a sustainable path of development is not an easy task for any Government. In 2005, the integration of different interests, ideas and activities into a three-year project to restore the Cheonggyecheon Stream in Seoul required often lengthy dialogues and negotiations. Under the leadership of the mayor, the city's political, business and residential communities found a way to coordinate their views on balanced urban growth and sustainable development. The rehabilitation of the local streams and improvements in water systems have enhanced resilience to floods.

The scope of technological transformation

Investments in climate change adaptation technologies can be part of building economic diversification strategies

The increased incidence of disasters and the higher likelihood of extreme events make investment in adaptation urgent. For the poorest countries, international cooperation will require emphasis on adaptation rather than on mitigation. For many developing countries, the demands of coping with the additional burdens of climate change will exceed domestic resources and require external support. In those countries, investment and technological choices will need to focus on addressing the most immediate hazards.

Reducing disaster risk in a sustainable manner will entail changes in the design of settlements and infrastructure, including roads, rail systems and power plants. Investments in technologies for adaptation must result in the installation of resilient infrastructures along with the creation of a diversified economy within the context of sustainable national development strategies (United Nations, 2008b; 2009).[2] Countries need to prepare a detailed assessment of their vulnerabilities, and of possible impacts of disasters, to establish priorities in respect of their responses. For example, the Federal Service for Hydrometeorology and Environmental Monitoring of the Russian Federation prepared impact indices for infrastructure depending on the frequency, intensity and duration of extreme weather events and climate volatility. In Siberia, as the level of risk to infrastructure built on permafrost has become increasingly unacceptable (owing to the reduction in the bearing capacity of permafrost soils in response to warmer weather), new building techniques are necessary to upgrade the infrastructure (United Nations Framework Convention on Climate Change, Subsidiary Body for Scientific and Technological Advice, 2010).

Existing technologies and knowledge systems for adaptation and disaster prevention

Technologies and knowledge systems for adaptation and disaster risk reduction are diverse and complex. Table IV.3 presents a typology of technology and knowledge systems for adaptation to and reduction of the adverse impacts of natural hazards.

2 See chap. II for an analysis of green technology strategies for climate change mitigation.

Table IV.3
Technology and knowledge-based systems for climate change adaptation

Adaptation strategy	*Floods*	*Droughts*	*Rise in sea level*	*Heatwaves*	*Storms*	*General adaptation technologies*
Infrastructure	Build dykes, gates and setback defences to protect coasts, industry and households; create upland buffers, reservoirs, floating communities/houses, and flood-resilient buildings/infrastructure	Create redundancy for aqueducts and water supply; build rainwater harvesting systems	Raise low-lying areas; elevate houses in high-risk zones; build floating communities and water plazas, sea walls and coastal defence structures; flood-proof new buildings	Modification of building design and construction	Implementation of sustainable urban drainage systems (storm water retention ponds, constructed wetlands)	Improve sanitation facilities in informal settlements; improve water treatment; genetic/molecular screening of pathogens
	Improve construction of low-income houses; housing construction in high-lying areas	Improve water supply infrastructure	Retrofitting; desalinization techniques	Plant trees	Improve construction of informal housing	Improve public transport; develop urban rail systems
	High-level storm sewers; fortify and adapt critical infrastructure, for example, larger diameters of pipes	Advanced recycling and efficient technologies in industrial cooling	Redevelop city parts	Urban shade-tree planting	Technology for monitoring and warning systems	Catalytic converters; tall chimneys
	Situate industrial systems away from vulnerable areas	New varieties of crops, irrigation systems, efficient windbreaks, erosion control techniques	Situate industrial systems away from vulnerable areas; use physical barriers to protect industrial installations	Installation of high albedo roofs; advanced recycling and efficient technologies in industrial cooling	Development of resilient infrastructure (storm water drainage, new sewage treatment installation); high-level storm sewers; flood proofing	Construction of sound housing for low-income groups
Regulation	Amend and enforce building standard codes; provide adequate flood insurance	Improve water efficiency standards	Amend and enforce building standard codes	Amend building codes	Improve regulation for informal housing	New buildings guidelines; emission controls
	Ban new buildings and increase land-use restrictions in high-risk zones/areas	Establish and enforce rules and regulations for water-use restrictions	Ban new buildings and increase land-use restrictions in high-risk zones/areas		Building standards (including in respect of increased risk of storms); amend building codes	New planning laws; traffic restrictions
	Improve regulation for informal settlements	Amend and enforce building standard codes				Watershed protection laws; water quality regulation

Table IV.3 (cont'd)

Adaptation strategy	*Floods*	*Droughts*	*Rise in sea level*	*Heatwaves*	*Storms*	*General adaptation technologies*
Management	Resettlement	Reduce pollution of freshwater; recycle water (grey water)	Resettlement	Urban greening programme; green roof programme; support green belts in the city	Monitoring, early warning and evacuation systems	In households, educate on removing items associated with transmission of water-borne diseases
	Update flood plain maps; implement/ update maps of flood evacuation zones	Develop comprehensive water strategy; integrate water resource planning	Monitor and assess climate impact indicators	Increase awareness of heat-related stress and management; heat-health alert system	Ban on new buildings in high-risk zones	City-wide strategic and integrated planning; urban planning to reduce heat island effects
	Training of task force to protect critical infrastructure	Change consumer behaviour	Local and regional climate models; systems for monitoring and early warning and evacuation systems	Public education on climate-related health threats; hygiene behaviour	Protection of mangrove forests	National health insurance schemes; vaccination; impregnated bednets; build-up of pit latrines
	Work with vulnerable neighbourhoods	Reduce leaking water pipes		Minimize paved surfaces	Task force to protect vital/critical infrastructure; use of storm shelters	Pollution warnings; boil-water alerts
	Establish emergency preparedness plans; establish public contingency plans	Establishment and training of task force to protect critical infrastructure; increase training in ecological fire management		Air quality management system; reduce energy required for air conditioning	Protect green belts that can help manage storm-water run-off	Lay out cities to improve efficiency of combined heat and power systems; optimize use of solar energy
	Improve flood warning and evacuation systems	Monitoring, early warning and evacuation systems; build awareness campaigns		Task force to protect vital/critical infrastructure	Protection of water catchment areas	Link urban transport to land-use patterns; promote mass public transportation; carpooling
		Temporary resettlement		Emergency preparedness plans	Emergency preparedness plans	Cluster homes, jobs and stores

Source: UN/DESA.

Technology policies in support of adaptation and disaster risk reduction can, based on their dimensions, be classified according to three categories: (a) infrastructure, (b) regulation and (c) management. High-level storm sewers and flood-proofing of new buildings, for example, come under infrastructure investment. New standards for water-use efficiency and improvement of building codes are examples of regulatory measures: Saint Lucia, for example, has revised its building codes so as to effect reduction in the adverse impacts of hurricanes, floods and extreme temperatures. The protection of mangrove forests, resettlement and green urban planning are examples of measures related to improving management expertise.

Most disaster reduction efforts can rely on known technologies and indigenous knowledge

As indicated in table IV.3, the building of floating communities, water plazas and coastal defence structures can be useful for tackling seawater-level rise as well as floods. Banning new buildings in high-risk zones can be useful for preventing the adverse impacts of storms and floods. Similarly, training to increase awareness of heat-related stress can be applied to reducing the impacts of droughts as well as heatwaves. The United Nations Framework Convention on Climate Change, Subsidiary Body for Scientific and Technological Advice (2010) notes that a rainwater harvesting system for the Caribbean Insular Area of Colombia, which has been effective in reducing pressure on the island aquifers, is also being used in the Plurinational State of Bolivia to reduce the adverse impact of droughts on the livelihoods of Aymara farmers.

From a consideration of the entries in the table, one concludes that the actions required for adaptation can rely heavily on known technologies and indigenous knowledge. The bigger challenge is to put into place the required technical capabilities and managerial skills to build dykes, improve construction of low-income housing, establish and enforce rules and regulations for water use, establish monitoring and early warning systems, and improve preparedness for emergencies and evacuation, all of which constitute key interventions for reducing disaster risk. Enhancing human resources in these areas is critical. Investments in disaster responses—including those that entail the expansion of infrastructure and basic services, which can have strong development impacts in the poorest countries—must be included in public sector planning. However, the set of disaster risk reduction projects does not constitute a development strategy. There are "hard choices" regarding how much of a country's limited investment resources can be devoted to these projects that have still to be made.

Technology gaps to be bridged

The scale of the required technological transformation will vary from context to context

As the scale of the required technological transformation will vary from context to context as a function of the degree of disaster risk, the adaptation technologies available, and the kinds of adaptation and disaster risk reduction strategies that countries have already put in place, the following questions will have to be asked: What is the degree of disaster risk for different countries? What are the actual adaptation technologies and knowledge systems in use? Which technological gaps should still be overcome? The choices to be made based on the answers must reflect the constraints on financial resources faced by many developing countries.

Although discussed in the relevant literature, not all of the existing adaptation technologies presented in the table have been widely used or integrated into ongoing projects. In fact, many of them have been implemented only in particular contexts and on differing scales. Annex IV.1 describes 25 ongoing adaptation projects selected from a databank of 135 (some of them including technological elements) operated in 70 countries.[3] Over 75 per cent of all projects tend to focus on the rural sector, attesting to what Birkmann and von Teichman (2010) have underscored, namely, that, in general, fewer adaptation strategies have been formulated for urban areas. The annex specifies the main types of disasters to which countries are subject, the kind of adaptation technologies being used, and the scale at which these are implemented.

About one third of all projects in the databank use technological strategies, often in combination with other components such as infrastructure, disaster risk reduction, awareness, planning and institution-building. The Grameen project, for example, combines technology and empowerment strategies by providing poor people with access to loans for home designs that are especially adapted to heavy rains and floods and, in addition, can be conveniently dismantled then reassembled in the face of severe flooding. Another advantage of this project is its national character, with the disaster-risk management sector integrated into the national development strategy of Bangladesh. Similarly, the Bogotá project, which reduces the risk of floods and landslides by improving risk-detection technology, emergency response, recovery finance, and awareness, uses a "cocktail" of tangible and intangible adaptation strategies, such as insurance, monitoring early warning systems, institution-building, improved infrastructure, and awareness, to achieve its objectives.

A national-scale project run by the Netherlands Climate Change Studies Assistance Programme operates along similar lines, focusing on institution-building, policy and efficient use of resource strategies in order to improve water management in Yemen. These projects demonstrate that technological improvement and capacity-building activities are central to increasing the resilience of vulnerable people, including women, children and older persons. In contexts where these groups have received equal access to preventive hazard management activities, the number of fatalities has been zero (World Bank, 2010a).

The United Nations Development Programme (UNDP) has also been active in facilitating technologies for climate change adaptation.[4] Tessa and Kurukulasuriya (2010) classify 29 UNDP country projects within four different cateogies: (a) projects implemented in the areas of agriculture/food security and water resources management (mainly in Africa), (b) projects on infrastructure for disaster risk management (in Asia, Africa and the Pacific), (c) projects designed to improve ecosystem management (forest, wetland and coastal ecosystems) and build capacity of stakeholders and institutions and (d) projects for sustainable land management whose aim is to improve the technical capacity of farmers and pastoralists and implement sustainable land management techniques.

Multinational projects to enhance adaptation technologies and risk reduction strategies are critical

Multinational projects set up to enhance adaptation technologies and risk reduction strategies are also important. For example, with the financial support of the World Bank, the Caribbean Community Secretariat is engaged in safeguarding the Community's coastal resources by enhancing risk communication strategies and running pilot projects designed to enhance the use of technology, planning methods and awareness campaigns. Similarly, the multinational rural project on disaster-risk management run by the non-governmental organization ActionAid engages communities in Bangladesh, Ghana, Haiti, Kenya, Malawi and Nepal in activities geared to making schools in high-risk areas safer, thereby enabling those schools to act as models during disaster risk reduction awareness campaigns. Strategies centred on raising awareness, institution-building and infrastructure investment support the implementation of this project.

3 The data bank was originally compiled by McGray, Hammill and Bradley (2007).

4 The Global Environment Facility (GEF) is the largest funder, with $66 million in grant contributions.

Facilitating multilateral adaptation projects is critical given the multidimensionality of the adverse impacts of many natural hazards. Box IV.2 offers an example of such a project, namely, the partnership between China and multilateral organizations established to strengthen technology-centred adaptation strategies.

Box IV.2

China's climate change adaptation programme and partnership framework

In the context of China's 2007 National Climate Change Strategy, the Government of China and a number of United Nations organizations[a] have signed off on a $19 million three-year joint programme to coordinate strategies and policies designed to enable communities to withstand the adverse impacts of climate change. The aim is to incorporate the Strategy into policies and legal measures, improve local capacities and partnerships for financing technology transfer and models, and ensure the adaptation of vulnerable communities to climate change.

Vulnerability assessment and adaptation constitute one of the major components of the programme, the other two being mitigation and climate change policy. The adaptation component addresses the areas of: (a) poverty reduction; (b) agriculture development in the Yellow River Basin, including vulnerability assessment and adaptation measures; (c) water management in the Yellow River Basin, including improved groundwater monitoring in high-risk areas; (d) a strategy for adapting China's health planning and practice to climate change; and (e) assessment of employment vulnerabilities and development of adaptation strategies.

While all of China is expected to feel the impact of climate change, poor areas are more vulnerable. In western China, glacial melting in the Himalayas and shifting patterns of land and water use for large upstream and downstream populations increase risks to livelihoods. On the south-east coast, rising sea levels threaten the lives of local people. Thus, vulnerability assessments and adaptation measures are needed, which tie in policies devised to eradicate poverty, combat diseases and ensure environmental sustainability.

Changes in temperature and precipitation have significant impacts on water resources. Analysis of the relation between climate change and hydrologic systems has proved useful in preventing water-related disasters. Owing to the increased reliance on groundwater in semi-arid and arid areas and the expected increased groundwater depletion and quality deterioration, assessment of actual changes in groundwater levels and quality and the impacts on livelihood is needed. This will allow for appropriate adjustment policies, including the imposing of restrictions and, where possible, the implementation of measures to recharge groundwater.

As climate change may lead to changes in the distribution of disease vectors and increases in vector-borne diseases, China's National Environment and Health Action Plan is focused on mainstreaming climate change into control policies for major health sensitive climate outcomes such as water stress/desertification, flooding, dust storms and smog, and on enhancing adaptive capacities.

The adverse impact of climate change on employment is still an unexplored area but the consequences are likely to be substantial. Major changes in crop distribution and yield would greatly affect people in rural areas and thus force migration into urban and industrial areas. There is a need for the Government and the commercial sector to assess the potential impacts on employment in order to formulate effective policies and responses. The focus on employment issues will complement and support other programme activities.

The programme intends to build on United Nations experience derived from past and ongoing projects and from grappling with high-level policy issues, to build on potential synergies among organizations in the United Nations family, to utilize the complementary support of other bilateral and multilateral organizations, and to focus on rural areas so as to maximize environmental and social co-benefits. The process of consultation among United Nations institutions and the Government of China, identification of priorities, creation of partnerships and pursuit of implementation and monitoring activities will all contribute to the creation of a model for replication in other countries.

Source: China climate change partnership framework document. Available from http://www.mdgfund.org/sites/default/files/China%20Environment_JP%20Signed.pdf.

a United Nations Environment Programme (UNEP), World Health Organization (WHO), Food and Agriculture Organization of the United Nations (FAO), International Labour Organization (ILO), United Nations Development Programme (UNDP), United Nations Educational Scientific and Cultural Organization (UNESCO), Economic and Social Commission for Asia and the Pacific/United Nations Asian and Pacific Centre for Agricultural Engineering and Machinery (ESCAP/UNAPCAEM), United Nations Children's Fund (UNICEF) and United Nations Industrial Development Organization (UNIDO).

Enabling sector-level disaster-resilient technological change

The energy challenge

The need to climate-proof clean energy plants and infrastructure should not be neglected

The technological transformation needed in the energy sector (see chap. II) requires the installation of new types of energy plants and infrastructure, most pervasively in developing countries. As climate-proofing these facilities and related infrastructure will be necessary, developing countries must build a domestic capability in building and maintaining such structures. Risk reduction specialists recommend that storage facilities, factories, buildings, roads and water and sanitation infrastructures be relocated or reinforced against the likely impacts of longer droughts, intense precipitation, floods and sea-level rise. More intense and frequent floods in Albania, for example, prompted the Government to build smaller hydropower plants and larger water channels. By delivering energy more efficiently, these plants have the potential to open up avenues for sustainable development.

Water and sanitation

The United Nations Framework Convention on Climate Change (2006) has discussed the inclusive framework for water management referred to as integrated water resource management (IWRM). This approach recognizes that water is a finite resource and that "(e)ssential water supplies should be accessible to all, and their distribution should be managed in a participatory fashion with a particular concern for the interests of the poor" (p. 16). This framework identifies forms of water-supply management that give consideration to ecosystems, including crop, livestock, fishing and forest activities.

Table IV.4 provides examples of adaptation technologies for water resources, which underline the multisectoral nature of water use and the dual (supply and demand) facets of adaptation technologies. Some technologies are traditional or locally based, for example, harvesting rainwater and building reservoirs and levees. Implementation of others requires specialized equipment or knowledge related, for example, to increased turbine efficiency and desalinization. Implementation of technologies for water management also requires regulatory mechanisms, such as the enforcement of water standards and the curbing of flood plain development.

Because of climate change, countries in warm areas will have to enhance their systems for safely storing and treating water

In order to respond to the increased risk of epidemic outbreaks from climate change, countries in warm areas will have to enhance their systems for safely storing and treating water, for example, through waste-water recycling and desalinization. Investing in reliable water-conserving technologies for delivering clean water will be required in the households and settlements of many developing countries. Sustainable urban drainage systems utilizing rainwater harvesting, for example, can enhance resilience to excessive rainfall and eliminate the threat of the production of contaminated water, which provides a habitat for disease vectors such as mosquitoes.

Water and sanitation systems must be made resilient with respect to the effects of heavy rainfalls and longer droughts. Ecological sanitation and toilet systems whose safe processing of human waste does not require water might become a key technology under water-scarce conditions.

Table IV.4
Adaptation technologies for water resources

Use category		*Supply side*	*Demand side*
Municipal or domestic		• Increase reservoir capacity • Desalinization • Make inter-basin transfers	• Recycle "grey" water • Reduce leakage • Use non-water-based sanitation systems • Enforce water standards
Industrial cooling		• Use lower-grade water	• Increase efficiency and recycling
Hydropower		• Increase reservoir capacity	• Increase turbine efficiency
Navigation		• Build weirs and locks	• Alter ship size and frequency of sailings
Pollution control		• Enhance treatment works • Reuse and reclaim materials	• Reduce effluent volumes • Promote alternatives to chemicals
Flood management		• Build reservoirs and levees • Protect and restore wetlands	• Improve flood warnings • Curb flood plain development
Agriculture	Rain-fed	• Improve soil conservation	• Use drought-tolerant crops
	Irrigated	• Change tilling practices • Harvest rainwater	• Increase irrigation efficiency • Change irrigation water pricing

Source: United Nations Framework Convention on Climate Change (2006), figure 5.

Health

Technologies for adaptation need to reduce the exposure of poor communities to the impacts of climate change by strengthening public-health systems and urban planning (including housing in risk-safe areas).

To deal with increased exposure to health risks, improved construction for housing and schools will be required

To deal with increased exposure to health risks, such as water- and vector-borne diseases, in areas where climate change will raise average temperatures, improved construction for housing and schools will be required. Adverse impacts of rising temperatures will require—just to protect health gains already achieved—increased investment in public-health infrastructure. Measures to reduce the health risks should be gender- and environment-sensitive, particularly in the context of development of technologies and public-health strategies.

Low-cost and low-technology solutions such as mosquito nets and water filters can be only a part of a larger integrated approach to building up effective public-health systems. Satellite mapping and geographical information systems, which are useful for local, regional and national surveillance of possible areas affected by malaria and other communicable diseases sensitive to climate shocks, allow health-care professionals to assess priorities, reallocate resources and prevent future outbreaks. The use of these technologies can be more effective if poor countries are able to access finance, knowledge and expertise.

Coastal zones

Sea-level rises endanger populations residing in low-elevation coastal zones

Sea-level rise increases the risk for populations residing in low-elevation coastal zones.[5] About 88 per cent of the people in low-elevation coastal zones (over half of whom live in urban areas) reside in developing countries. Low-elevation coastal cities such as Lagos, Cape Town, Maputo and Mombasa often have large concentrations of low-income urban-dwellers. Sites of economic production and strategic infrastructure concentrated in these cities are also vulnerable to climate change. Table IV.5 demonstrates that some of the most populous developing countries, such as China, India, Bangladesh, Viet Nam and Indonesia, have the largest number of people living in these zones. The table also indicates that among the top 10 countries with the highest shares of population in the low-elevation coastal zones, 8 are low-income or lower-middle-income countries.

Table IV.5
Countries with the largest total population and with the largest share of their population in a low-elevation coastal zone (LECZ), 2000

Top 10	*Country*	*Rank by total population in the LECZ (millions)*	*Country*	*Rank by share of population in the LECZ (percentage)*
1	China	143,880	Bahamas	88
2	India	63,188	Suriname	76
3	Bangladesh	62,524	Netherlands	74
4	Viet Nam	43,051	Viet Nam	55
5	Indonesia	41,610	Guyana	55
6	Japan	30,477	Bangladesh	46
7	Egypt	25,655	Djibouti	41
8	United States of America	22,859	Belize	40
9	Thailand	16,478	Egypt	38
10	Philippines	13,329	Gambia	38

Source: McGranahan, Balk and Anderson (2007), table 3.

Note: Countries or areas with a total population of under 100,000 people or smaller than 1,000 square kilometres were excluded from this list. If all countries had been included, 7 of the top 10 in the table would be countries or areas with fewer than 100,000 persons, the top 5 having more than 90 per cent of country or area in the Low Elevation Coastal Zone (Maldives, Marshall Islands, Tuvalu, Cayman Islands and Turks and Caicos Islands).

Three basic adaptation strategies are available to coastal communities and countries: protection, retreat and accommodation. For protection, "hard" options such as sea walls and "soft" options, such as restoring dunes, creating and restoring coastal wetlands, and reforestation, could be relevant. For retreat, the following might be appropriate: the requirement that setback zones for development be at a specific distance from the water's edge; legal restrictions on size and density of structures within risky areas; and specification of permitted forms of shoreline stabilization. In respect of accommodation, warning systems for extreme weather events, new building codes, and draining systems with increased pump capacity and wider pipes would be paramount (United Nations Framework Convention on Climate Change, Subsidiary Body for Scientific and Technological Advice, 2010).

More broadly, policy action on technological adaptations for new settlements encompasses three dimensions: (a) energy-efficient technology for new building structures;

5 Low-elevation coastal zones are defined as land areas contiguous with the coastline up to a 10-metre rise in elevation and whose width is often less than 100 kilometres.

(b) planning of settlements, including construction of appropriate infrastructure to protect against flooding (Netherlands), creation of green areas as flood buffers (Brazil) and design of multi land use cities to ease transportation and improve biodiversity (Seoul); and (c) making city services climate-friendly, for example, by offering affordable and efficient public transportation and adequate housing (see box IV.3).

Box IV.3

Green restoration projects in the Republic of Korea

Levels of flooding and drought are likely to worsen in the Republic of Korea and the threat of water scarcity and water overabundance becomes most acute when one considers demand and supply in the context of possible future socio-economic and natural changes. In order to respond effectively to expected climate irregularities, water control policies are becoming increasingly necessary.

Securing water resources is a critical dimension of climate change adaptation. In this regard it is planned, as part of the Four Major Rivers Restoration Project, that about 1.3 billion cubic metres of water will have been secured by 2012. The Project, launched in 2009, entails restoration of the Han, Nakdong, Geum and Yeongsan rivers and includes a number of related projects on their tributaries. A significant portion of the funds for adaptation ($28 billion) will be utilized for the Project (the total investment for "greening" the economy of the Republic of Korea is about $84 billion).

The project has five objectives: (a) to counter water scarcity by securing abundant water resources; (b) to implement well-coordinated measures for flood control; (c) to improve water quality and restore ecosystems; (d) to create multi-purpose spaces for local residents; and (e) to promote climate-resilient regional development centred on rivers. Overall, it is expected that the project will create 340,000 jobs and generate an estimated 40 trillion won ($31.1 billion) in positive economic effects.

The development of ecological defence systems will be continued through the setting up of forest protection and forest ecosystem management programmes. The Republic of Korea aims to increase the capacity of national forest resources from 862 million to 953 million cubic metres by enhancing forest protection and forest ecosystem management programmes. Forests and wetlands prevalent in a large part of the Korean Peninsula are being properly conserved and made more resilient so as to provide natural defences against storms, cyclones, flooding and sea-level rise.

The implementation of ecological restoration through reforestation can significantly enhance resilience. The review, under the UNEP-led study on the Economics of Ecosystems and Biodiversity, of a large number of restoration projects suggests that through ecological restoration, resilience improvements can be achieved in three significant areas of adaptation: (a) freshwater security; (b) food security (involving both artisanal fisheries and small-farm productivity); and (c) management of natural hazard risks (cyclones, storms, floods and droughts).

Source: United Nations Environment Programme (2010b).

Institutional change and capacity building

For disaster risk reduction technologies to be put in place effectively in poor countries, those countries need to strengthen their institutions. The United Nations Framework Convention on Climate Change[6]—acting under the Technology Transfer Framework—assessed the institutional gaps in developing countries in the course of undertaking technology needs assessments. Technology needs assessments track the need for new equipment and techniques ("hard technology") and for the practical knowledge and skills ("soft technology") required to adapt and reduce vulnerability to the adverse impacts of climate change (Hecl, 2010). In their technology needs assessments 68 countries highlighted capacity development as a technology priority.

6 United Nations, *Treaty Series*, vol. 1771, No, 30822.

It is crucial for Governments and the international community to support investment in capacity development, including in higher education focused on technologically oriented careers and in programmes that promote practices of sustainable consumption. The Government of Nigeria provides such support through a programme, in which specially trained instructors educate primary and post-primary school children in Lagos on climate change effects and environmental management. The young people then act as agents of change by reaching out to the larger society. "Climate change clubs" have been established in many primary and post-primary institutions having trained instructors.

The training of the next generation of technicians and professionals must be actively supported

Building local innovation capacity in developing countries is essential for the adaptation of renewable energy technologies. The training of the next generation of technicians and professionals must be actively supported, and national innovation plans should include support for local education and research and for their linkages with international innovation centres (United Nations, Department of Economic and Social Affairs, 2009).

Extension programmes can be important for building capacity among low-income urban communities

The challenge is to create institutional mechanisms that facilitate access of vulnerable communities not only to knowledge and finance but also to adaptation technologies. Fiscal systems whose purpose will be to transfer resources to technologically disadvantaged economic sectors and less educated populations need to be widely explored and carefully designed so as to reduce the impact of negative responses. Likewise, the active participation of all stakeholders, both women and men, in the implementation of adaptation technologies can promote greater support for the benefits of adaptation.

Extension programmes can be an important means of sharing information on technology transfer, building capacity among low-income urban communities and encouraging residents to form their own networks. Community organizations, for example, can be an effective information-sharing mechanism with the potential to provide cost-effective links between government efforts and community activities, while investment incentives and tax relief can entice the local private sector into engaging in technology transfer. Non-governmental organizations can play the role of intermediaries by facilitating investment, identifying adaptation technologies, and providing management and technical assistance.

Engaging the private sector requires the strengthening of countries' institutional base, including the provision of incentives to support, for example, architectural changes, hazard insurance and development of new consumer products. Policies to induce the participation of private insurance companies in the enforcement of standards can also be appropriate.

Financing and external transfers

Ballpark figures suggest that the cost of the resources needed for adaptation are significant but not prohibitive.

Adaptation technologies can be classified by sector and by stage of technological maturity (see table IV.6). The agriculture, livestock and fisheries sector lays claim to the bulk of these technologies, followed by the coastal zones and infrastructure sectors. The early warning and forecasting sector utilizes the largest number of technologies classified as "high". Global estimates for the additional annual investment and financial flows needed for technological adaptation to the adverse effects of climate change range from \$32.6 billion to \$163.1 billion in 2030 (United Nations Framework Convention on Climate Change, Subsidiary Body for Scientific and Technological Advice, 2009, table 8). These estimates, which include the costs of infrastructure, health, water supply and coastal

Table IV.6
Climate change adaptation technologies, by sector and stage of technological maturity[a]

	Adaptation technologies		Percentage of technologies that are:		
Sector	*Number*	*Percentage*	*High*	*Modern*	*Traditional*
Coastal zones	27	16.4	18.5	25.9	55.6
Energy	6	3.6		33.3	66.7
Health	18	10.9	38.9	38.9	22.2
Early warning and forecasting	13	7.9	84.6	15.4	
Infrastructure	23	13.9	8.7	47.8	43.5
Terrestrial ecosystems	8	4.8		25.0	75.0
Water resources	28	17.0	25.0	46.4	28.6
Agriculture, livestock and fisheries	42	25.5	21.4	31.0	47.6
Total	**165**	**100.0**	**41.0**	**57.0**	**67.0**

Source: United Nations Framework Convention on Climate Change, Subsidiary Body for Scientific and Technological Advice (2009), table 11. For the list of adaptation technologies, see annex II, table 20.

a Traditional/indigenous technologies are those that have been first developed in traditional societies to respond to specific local problems. Modern technologies comprise approaches that have been created since the first industrial revolution, including the use of synthetic materials, modern medicines, hybrid crops, modern forms of transportation and new chemicals. High technologies comprise technologies created based on recent scientific advances, including information and communications technology, computer monitoring and modelling, and engineering of genetically modified organisms.

projects, are based on assumptions on the likely course of climate change, although more detailed and localized studies are required to improve their accuracy. Further, assisting developing countries in obtaining realistic estimates on climate change impacts and extreme events will also improve the quality of the global database. While these numbers reflect a great deal of uncertainty, as the ballpark figures they suggest that the cost of the resources needed for adaptation is significant but not prohibitive.

In comparison with existing estimates, the Cancun commitment can be seen as only a first step in funding transfers to developing countries for climate change purposes

Under the Cancun Adaptation Framework, it was recognized "that developed country Parties (would) commit to … a goal of mobilizing jointly USD 100 billion per year by 2020 to address the needs of developing countries" (see FCCC/CP/2010/7/Add.1, decision 1/CP.16, para. 98). In comparison with existing estimates, the Cancun commitment can be seen as a modest first step in funding transfers to developing countries for climate change purposes. These funds would come "from a wide variety of sources, public and private, bilateral and multilateral, including alternative sources" (ibid., para. 99) with a "significant share of new multilateral funding for adaptation (flowing) through the Green Climate Fund" (ibid., para. 100).

The institutional mechanism that will implement and monitor the use of the "significant share" to be allocated for adaptation purposes has yet to be determined. It is clear, however, that the implementation of sustainable development plans in poor countries depends on stable sources of local finance and effective mobilization of resources at the international level. Concrete steps need to be taken to respond to the needs of developing countries.

The way forward

Domestic social priorities will shape how much technology and investment spending can be directed towards reducing longer-term hazards and truly catastrophic events

Drawing on indigenous knowledge, adapting existing technologies for the purpose of building infrastructure and housing and installing monitoring and response systems provide the key to successful disaster risk reduction efforts. However, investments in disaster risk reduction are constrained by competing investment claims on a finite public sector budget. Faced with the knowledge that one extreme disaster can wipe out the gains of decades of development investment, every society will still have to decide how much of its resources can be devoted to disaster risk reduction efforts. While projects designed to deal with seasonal and well-known risks would normally be given investment priority, domestic social priorities will shape how much technology and investment spending can be directed towards reducing longer-term hazards and truly catastrophic events. It is therefore critical that disaster risk reduction and climate change adaptation efforts be incorporated in national development strategies in order to ensure that priorities for disaster risk management are defined within that context.

Transborder natural hazards will require strengthening regional cooperation in the area of monitoring, forecasting and warning systems. Countries could also cooperate in disaster risk assessments and undertake multinational projects in risk reduction.

The longer-term hazards being imposed by climate change are global in source, but local in impact

The longer-term hazards being imposed by climate change are global in source, but local in impact. Global cooperation will require facilitating technology transfer to developing countries. So that the advantages of foreign technology in adaptation and risk reduction projects can be realized, technology transfer should ensure that recipients have the capacity to install, operate, maintain and repair imported technologies. It might also be important for local adapters to be able to produce lower-cost versions of imported technologies and adapt imported technologies to domestic markets and circumstances. The international community has made a commitment to providing external assistance to local adaptation programmes and while most estimates suggest that the overall call on adaptation resources is not prohibitive, the operational modalities for predictable and adequate resource flows to developing countries still need to be agreed upon (see chap. VI).

By protecting livelihoods against disaster, disaster risk reduction and climate change adaptation projects contribute to development

By protecting livelihoods against disaster, disaster risk reduction and climate change adaptation projects contribute to development (United Nations, 2008b). As noted, such projects have synergies with other development imperatives, including in the areas of construction, housing, transportation systems, basic services provisioning, manufacturing and employment absorption. The effort to manage the needed adaptation of both foreign and indigenous technology so as ensure the reduction of the impact of natural disasters and climate change should be embedded in the larger project of achieving national industrial development and innovation. This subject will be taken up in chapter V.

Annex table IV.1
Projects encompassing technological strategies for adaptation and disaster risk reduction

Country	*Highest disaster incidence, 1990-2009*	*Adverse impacts of changing environment*	*Strategies employed*	*Scale*	*Case description*
Argentina	Floods (29)	Damage to human settlements; decline in productivity of fisheries; decrease of crop yields; flooding; drought and aridity	Empowerment	Community (rural)	Argentina's rural electrification project grants scattered communities access to the technological and educational benefits of electricity, thereby helping them become resilient to floods, droughts and crop loss.
Bangladesh	Storms (84)	Water shortages; landslides; decrease of crop yields; decline in productivity of livestock and/or poultry; drought and aridity; flooding	Agriculture; resources; technology; empowerment	Community (rural)	**South***South*North and the Society for Wetland Eco-Research are implementing several measures (for example, crop diversification, disaster preparedness) targeting the threat of sea-level rise and storms.
Bangladesh	Storms (84)	Damage to human settlements; flooding	Technology; empowerment	National (urban and rural)	The Grameen Bank provides loans for two house designs that are specially adapted to heavy rains and floods, and can even be dismantled and reassembled, in severe flood events.
Colombia	Floods (42)	Flooding; landslides	Insurance; monitoring and early warning systems; institutions; infrastructure; awareness	Subnational (urban)	Concerned about floods and landslides, Bogota is improving risk-detection technology, emergency response, recovery finance and awareness.
Cuba	Storms (21)	Coastal inundation or erosion	Resources; infrastructure	National (urban and rural)	Cuba has developed beach restoration technology to restore ecological and functional value of its coasts.
India	Floods (141)	Water shortages; flood, drought	Technology	Subnational (rural)	Tarun Bharat Sangh (a non-governmental organization) has facilitated the construction of earthen check dams to retain monsoon water for times of drought.
Indonesia	Floods (85)	Damage to human settlements; flooding	Awareness; institutions; monitoring and early warning systems; planning	Community (urban)	The Red Cross is establishing institutional structures and in East Jakarta plans to take a proactive approach to climate change, including through awareness-raising and an early warning system.

Annex table IV.1 (cont'd)

Country	*Highest disaster incidence, 1990-2009*	*Adverse impacts of changing environment*	*Strategies employed*	*Scale*	*Case description*
Madagascar	Storms (29)	Drought and aridity; flooding	Monitoring and early warning systems; awareness; resources	National (rural)	WWF and Conservation International are analysing and raising awareness of the vulnerability of marine and terrestrial environments to climate change.
Mali	Floods (14)	Decrease of crop yields	Monitoring and early warning systems; awareness; technology	National (rural)	The Government of Mali and the Swiss Agency for Development and Cooperation use data collected by farmers to help them make planting decisions.
Mozambique	Floods (17)	Water shortages; drought and aridity	Technology; resources	Community (rural)	**South***South*North and local partners are supplying farmers with renewable energy to combat water shortage.
Multinational (Cameroon, Fiji, Tanzania (United Republic of))	Floods (37)	Flooding	Resources; planning; technology; institutions	Multinational (rural)	WWF is testing methods to restore degraded mangrove forests so as to make them resilient with respect to climate change.
Multinational (Bangladesh, Ghana, Haiti, India, Kenya, Malawi, Nepal)	Floods (297)	-	Institutions; awareness; policy; infrastructure	Community (urban and rural)	ActionAid is making schools in high-risk disaster areas safer, enabling them to act as models in disaster risk reduction.
Multinational (Southern African countries: Angola, Botswana, Comoros, Democratic Republic of the Congo, Madagascar, Malawi, Mozambique, Namibia, South Africa, Swaziland, Tanzania (United Republic of), Zambia, Zimbabwe)	Floods (157)	Spread of vector-borne diseases	Monitoring and early warning systems;	Multinational (urban and rural)	The Roll Back Malaria Initiative developed a monitoring and early warning system which uses climatic data to predict malaria outbreaks.
Multinational (West African countries: Cape Verde, Gambia, Guinea-Bissau, Mauritania, Senegal)	Floods (32)	Coastal inundation or erosion; decline in productivity of fisheries; biodiversity loss	Planning	Community (urban and rural)	UNDP is incorporating climate change concerns, such as coastal erosion and declining fish stocks, into integrated coastal management.
Nepal	Floods (20)	Damage to human settlements; flooding	Technology	Community (rural)	An intermediate technology development group project reduces the impact of floods by strengthening the capacity of local communities to set up early warning systems.

Annex table IV.1 (cont'd)

Country	*Highest disaster incidence, 1990-2009*	*Adverse impacts of changing environment*	*Strategies employed*	*Scale*	*Case description*
Nicaragua	Storms (15)	Landslides; flooding	Technology; monitoring and early warning systems	Community (rural)	The autonomous government of the North Atlantic Region has improved its early warning systems and disaster planning in order to cope with storms and floods.
Peru	Floods (23)	Decrease of crop yields; drought and aridity; flooding	Technology	Community (rural)	The waru waru restoration project has revived an ancient canalization technique designed to provide moisture to farms during drought, and drainage during heavy rains.
Philippines	Storms (136)	Flooding; drought and aridity	Resources; technology	Subnational (rural)	Oxfam set up a relief and rehabilitation programme in response to increased storms, droughts, floods and warfare. The programme includes food and medicine provision and credit and training for entrepreneurship.
Samoa	Storms (4)	Storm	Resources	Community (rural)	Matafa village is conserving nearby mangroves to safeguard biodiversity, provide income and protect the village from storm surges.
Samoa	Storms (4)	Flooding	Resources	Community (rural)	Lepa-Komiti Tumama is helping the village of Lepa store clean drinking water for use during floods.
South Asia (Bhutan, India, Nepal, Pakistan) Note: Data for China/Tibet not reported separately.	Floods (211)	Glacial lake outburst floodings; flooding	Monitoring and early warning systems	Multinational (urban and rural)	International Centre for Integrated Mountain Development is developing a database and early warning system for glacial lake outburst floods.
Tajikistan	Floods (19)	Water shortages; flooding; drought and aridity; landslides	Technology; institutions; policy	National (rural)	Oxfam is addressing the water provision problems associated with droughts and flooding by introducing new technologies, promoting new crops, and launching a disaster preparedness programme.

Annex table IV.1 (cont'd)

Country	*Highest disaster incidence, 1990-2009*	*Adverse impacts of changing environment*	*Strategies employed*	*Scale*	*Case description*
Tanzania (United Republic of)	Floods (22)	Decrease of crop yields	Technology; planning	Subnational (urban and rural)	United Republic of Tanzania is preparing for climate change impacts on the Pangani River by improving technical knowledge and watershed management.
Thailand	Floods (49)	Damage to human settlements; flooding	Technology; agriculture; resources	Community (rural)	As an example of autonomous adaptation, communities in the lower Songkhram River basin have modified their fishing gear and rice-growing strategies to adapt to climate changes such as flooding and drought.
Yemen	Floods (21), Storms (2)	Water shortages; drought and aridity	Resources; institution-building; policy	National (urban and rural)	Netherlands Climate Change Studies Assistance Programme in Yemen focuses on social-based adaptation to climate change, especially the water use planning.

Source: UN/DESA, based on McGray, Hammill and Bradley (2007).

Note:

Strategies employed comprise: agriculture: changing agricultural practices; awareness: raising awareness; empowerment: empowering people; infrastructure: improving infrastructure; institutions: building institutions; monitoring and early warning systems: establishing monitoring/early warning systems; planning: launching planning processes; policy: promoting policy change; resources: changing natural resource management practices; technology: promoting technology change.

Blue shading denotes UNDP projects.

Yellow shading denotes technological strategies.