2

Climate shocks: risk and vulnerability in an unequal world

“The countries most vulnerable are least able to protect themselves. They also contribute least to the global emissions of greenhouse gases. Without action they will pay a high price for the actions of others.”

Kofi Annan

“Like slavery and apartheid, poverty is not natural. It is man-made and it can be overcome and eradicated by the actions of human beings.”

Nelson Mandela

CHAPTER 2 Climate shocks: risk and vulnerability in an unequal world

It is easy to lose sight of the human face of the people who are most vulnerable to climate change

"Hurricane Jeanne took all that I had...my job and my home are gone. I used to have food. Now I beg in the market."

Rosy-Claire Zepherin, Gonaives, Haiti, 2005[1]

"We are eating only a little once a day to make the maize last longer, but even then it will last only a short time. Then we are in trouble."

Margaret Mpondi, Mphako, Malawi, 2002[2]

"If the rains fail like they did last year we will go hungry. The rich have savings. They have stocks of food. They can sell their oxen for cash. But what do I have? If I sell my ox how will I plant next year? If my crop fails we have nothing. It is always like that. Everything depends on rain."

Kaseyitu Agumas, Lat Gayin, southern Gonda, Ethiopia, 2007[3]

"We had never seen such floods before. Lots of houses were destroyed, lots of people died, our agricultural land was submerged, crops stored in houses were lost. Many livestock were lost too. We were just not prepared to face such big flooding. So we didn't have any savings of money or food."

Pulnima Ghosh Mahishura Gram Panchayat, Nadia District, West Bengal, India, 2007[4]

"There are more floods now and the river banks are being washed away faster. There's nowhere to go. My land is in the river, I have nothing now."

Intsar Husain, Antar Para, north-western Bangladesh, 2007.[5]

Climate science deals in measurement. Emissions of carbon dioxide (CO_2) are weighed in tonnes and gigatonnes. Concentrations of greenhouse gases in the Earth's atmosphere are monitored in parts per million (ppm). Confronted with the data, it is easy to lose sight of the human face of the people who are most vulnerable to climate change—people such as those quoted above.

The human face of climate change cannot be captured and packaged in statistics. Many of the current impacts are impossible to separate from wider pressures. Others will happen in the future. There is uncertainty about the location,

What the world's poor are facing is a relentless increase in the risks and vulnerabilities associated with climate

timing and magnitude of these impacts. However, uncertainty is not a cause for complacency. We know that climate-related risks are a major cause of human suffering, poverty and diminished opportunity. We know that climate change is implicated. And we know that the threat will intensify over time. In chapter 1 we identify catastrophic future risks for the whole of humanity as one of the most powerful grounds for urgent action in tackling climate change. In this chapter we focus on a more immediate potential catastrophe: the prospect of large-scale human development reversals in the world's poorest countries.

That catastrophe will not announce itself as a 'big bang' apocalyptic event. What the world's poor are facing is a relentless increase in the risks and vulnerabilities associated with climate. The source of these incremental risks can be traced through climate change to energy consumption patterns and political choices in the rich world.

The climate already figures as a powerful force in shaping the life chances of poor people. In many countries, poverty is intimately related to repeated exposure to climate risks. For people whose livelihoods depend on agriculture, variable and uncertain rainfall is a potent source of vulnerability. For urban slum dwellers, floods pose a constant threat. Across the world, the lives of the poor are punctuated by the risks and vulnerabilities that come with an uncertain climate. Climate change will gradually ratchet up these risks and vulnerabilities, putting pressure on already over-stretched coping strategies and magnifying inequalities based on gender and other markers for disadvantage.

The scale of the potential human development reversals that climate change will bring has been heavily underestimated. Extreme climate events such as droughts, floods and cyclones are terrible occurrences in their own right. They bring suffering, distress and misery to the lives of those affected, subjecting whole communities to forces beyond their control and providing a constant reminder of human frailty. When climate shocks strike, people must first deal with the immediate consequences: threats to health and nutrition, the loss of savings and assets, damage to property, or the destruction of crops. The short-term costs can have devastating and highly visible consequences for human development.

The long-term impacts are less visible but no less devastating. For the 2.6 billion people who live on less than US$2 a day climate shocks can trigger powerful downward spirals in human development. Whereas the rich can cope with shocks through private insurance, by selling off assets or by drawing on their savings, the poor face a different set of choices. They may have no alternative but to reduce consumption, cut nutrition, take children out of school, or sell the productive assets on which their recovery depends. These are choices that limit human capabilities and reinforce inequalities.

As Amartya Sen has written: "The enhancement of human capabilities also tends to go with an expansion of productivities and earning power."[6] The erosion of human capabilities has the opposite effect. Setbacks in nutrition, health and education are intrinsically damaging, reducing the prospects for employment and economic advancement. When children are withdrawn from school to help their parents make up income losses, or suffer malnutrition because of reduced food availability, the consequences can stay with them for their whole lives. And when poor people suddenly lose the assets they have built up over years, this reinforces their poverty and holds back efforts to reduce vulnerability and extreme deprivation in the medium to longer term. Single climate shocks can thus create cumulative cycles of disadvantage that are transmitted across generations.

Climate change matters because it can be expected to increase the intensity and frequency of climate shocks. Over the medium and long term, outcomes will be influenced by the international mitigation effort. Deep and early cuts in carbon emissions would diminish the incremental risks associated with climate change from the 2030s onwards. Until then, the world in general, and the world's poor in particular, will have to live with the consequences of past emissions. That is why, as argued in chapter 4, adaptation strategies are so critical for human development prospects.

In this chapter we look at the past impacts of climate shocks on human development

in order to cast a light on future threats. We draw a critical distinction between risk and vulnerability. Climate risk is an external fact of life for the entire world. Vulnerability is something very different. It describes an inability to manage risk without being forced to make choices that compromise human well-being over time. Climate change will strengthen the transmission mechanisms that convert risk into vulnerability, militating against the efforts of the poor to advance human development.

The first section of this chapter sets out the evidence on a range of climate impacts. It examines the distribution of exposure to climate disasters and the long-run consequences of these disasters on human development. In the second section we use climate scenarios developed by the IPCC and others to examine the mechanisms through which the incremental risks generated by climate change might impact on human development during the 21st Century.

Climate risk is an external fact of life for the entire world. Vulnerability is something very different

2.1 Climate shocks and low human development traps

Climate disasters have been a recurrent theme in human history. Plato's Atlantis myth captures the destructive power of floods. The collapse of the Mayan civilization was triggered by a succession of droughts. The 21st Century has already provided some potent reminders of the frailty of people in the face of extreme climate.

Climate disasters are increasing in frequency and touching the lives of more people. The immediate consequences are horrific. But climate shocks are also reinforcing wider risks and vulnerabilities, leading to long-term setbacks for human development.

Climate disasters—the rising trend

Extreme climate events are a source of mounting concern across the world. In recent decades, the number of people affected by climate disasters such as droughts, floods and storms has been rising. Almost every disaster is accompanied by speculation about possible links to climate change. As climate science develops it will provide clearer insights into the relationship between global warming and weather system outcomes. However, current evidence points very clearly in one direction: namely, that climate change will increase the risk of exposure to climate disaster.

Reported climate disasters are on a rising trend. Between 2000 and 2004 an average of 326 climate disasters was reported each year. Some 262 million people were affected annually from 2000 to 2004, more than double the level in the first half of the 1980s (figure 2.1).[7]

Rich countries have registered a mounting roll-call of climate disasters. During 2003, Europe was hit by the most intense heat wave in more than 50 years—an event that caused thousands of deaths among the elderly and other vulnerable people. A year later, Japan was hit by

Figure 2.1 Climate disasters are affecting more people

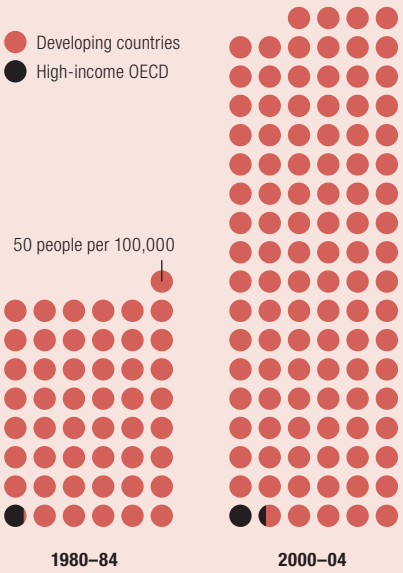
Source: HDRO calculations based on OFDA and CRED 2007.

For the period 2000–2004, on an average annual basis one in 19 people living in the developing world was affected by a climate disaster

more tropical cyclones than in any other year over the previous century.[8] In 2005, Hurricane Katrina, one event in the worst Atlantic hurricane season on record, provided a devastating reminder that even the world's richest nations are not immune to climate disaster.[9]

The intensive media coverage that accompanies climate disasters in rich countries ensures widespread public awareness of the impacts. It also creates a distorting prism. While climate disasters are affecting more and more people across the world, the overwhelming majority lives in developing countries (figure 2.2). For the period 2000–2004, on an average annual basis one in 19 people living in the developing world was affected by a climate disaster. The comparable figure for OECD countries was one in 1,500 affected—a risk differential of 79.[10] Flooding affected the lives of some 68 million people in East Asia and 40 million in South Asia. In sub-Saharan Africa 10 million were affected by drought and 2 million by flooding, in many cases with near simultaneous episodes. Here are some examples of events behind the reported headline numbers:[11]

Figure 2.2 **Disaster risks are skewed towards developing countries**



Source: HDRO calculations based on OFDA and CRED 2007.

- The 2007 monsoon period in East Asia displaced 3 million people in China, with large tracts of the country registering the heaviest rainfall since records began. According to the China Meteorological Association, the floods and typhoons of the previous year caused the second deadliest toll on record in terms of lives lost.
- Monsoon floods and storms in South Asia during the 2007 season displaced more than 14 million people in India and 7 million in Bangladesh. Over 1,000 people lost their lives across Bangladesh, India, southern Nepal and Pakistan.
- The 2006/2007 cyclone season in East Asia, which saw large areas of Jakarta flooded, displaced 430,000 people, with Hurricane Durian causing mudslides and extensive loss of life in the Philippines, followed by widespread storm damage in Viet Nam.
- In terms of overall activity, the 2005 Atlantic hurricane season was the most active on record. Hurricane Katrina made most of the headlines, causing widespread devastation in New Orleans. However, the 27 named storms of the season—including Stan, Wilma and Beta—affected communities across Central America and the Caribbean. Hurricane Stan caused the deaths of more than 1,600 mainly Mayan people in the Central Highlands of Guatemala—a greater human toll than Hurricane Katrina.[12]
- Droughts in the Horn of Africa and southern Africa during 2005 threatened the lives of over 14 million people across a swathe of countries from Ethiopia and Kenya to Malawi and Zimbabwe. In the following year, drought gave way to extensive flooding across many of the same countries.[13]

Reported data on the numbers affected by climate disasters provide important insights. However, the data captures only the tip of the iceberg. Many local climate disasters go unreported, or under-reported—and many more do not figure at all, because they do not meet the criteria for a humanitarian disaster (box 2.1).

Gender bias in the impact of disasters is also under-reported. When disasters strike, they hurt whole communities—but women often bear the

Box 2.1 Under-reporting climate disasters

Figures on climate-related disasters come from the EM-DAT *International Disasters Database* maintained by the Centre for Research on the Epidemiology of Disasters (CRED). The database has played a valuable role in improving the flow of information on disasters over time. However, it has certain limitations.

Sources for EM-DAT range from government agencies and the UN system to NGOs, insurance companies and press agencies. Some events are more reported than others: high-profile disasters like Hurricane Katrina attract more media attention than local droughts. Similarly, some groups are almost certainly under-reported: slum dwellers and people living in remote or marginal rural areas are examples.

The criteria for an event being categorized as a disaster are restrictive. Eligibility requirements include numbers killed or affected (at least 10 and 100 respectively), the declaration of a national emergency, or a call for international assistance. Some climate disasters do not meet these criteria. For example, during 2007, just over 1 million people in Ethiopia were receiving drought relief under international aid programmes that registered on the climate disasters database. Seven times this number were receiving support under a national programme to protect nutrition levels in drought-prone areas. That programme did not figure in the database because it was not counted as humanitarian aid.

There are wider sources of under-reporting. During 2006 a crisis caused by late rains in Tanzania did not figure in the CRED database. However, a national food security vulnerability assessment found that the event and rising food prices had left 3.7 million people at risk of hunger, with 600,000 destitute. Disaster statistics also fail to expose the imminent risks faced by the poor. In Burkina Faso, for example, a good harvest in 2007 meant that the country did not make an emergency food aid appeal. Even so, the United States Agency for International Development (USAID) food security assessment warned that over 2 million people were at risk of food insecurity in the event of any disruption to rainfall.

Finally, the disasters database provides a snapshot of numbers affected immediately after the event, but not subsequently. When Hurricane Stan struck Guatemala in October 2005, it affected half a million people, the majority of them from poor, indigenous households in the Western Highlands. They figured in the database for that year. During 2006, food security assessments showed that many of those affected had been unable to restore their assets and that production by subsistence farmers had not recovered. Meanwhile, food prices had increased sharply. The result was an increase in chronic malnutrition in areas affected by Hurricane Stan. That outcome represented a local disaster that was not recorded in the database.

Source: Hoyois et al. 2007; Maskrey et al. 2007; USAID FEWS NET 2006.

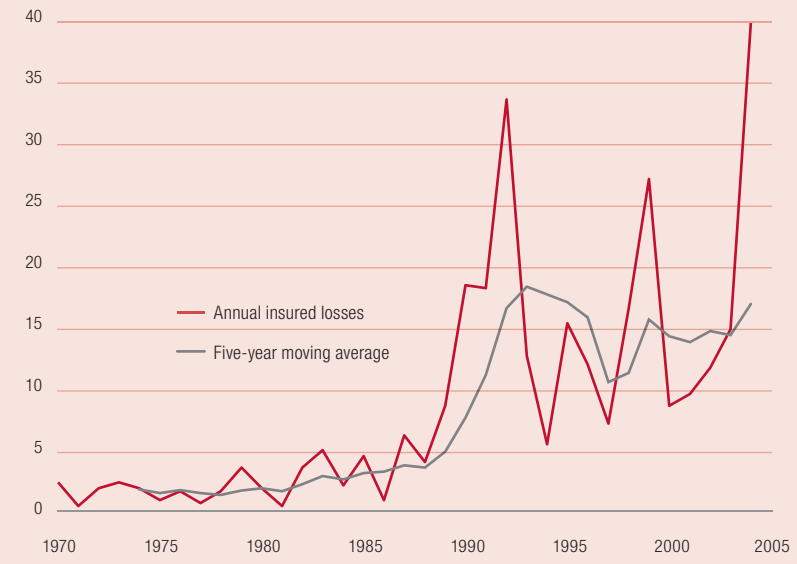
brunt. Floods frequently claim far more female victims because their mobility is restricted and they have not been taught to swim. When Bangladesh was hit by a devastating cyclone and flood in 1991, the death rate was reportedly five times higher among women. In the aftermath of a disaster, restrictions on the legal rights and entitlements of women to land and property can limit access to credit needed for recovery.[14]

Reported economic losses also paint a distorted picture. While over 98 percent of people affected by climate disasters live in developing countries, economic impacts are skewed towards rich countries. The reason for this is that costs are assessed on the basis of property values and insured losses, which have been rising steeply (figure 2.3). All eight of the climate disasters registering more than US$10 billion in damages reported since 2000 took place in rich countries, six of them in the United States.

Insurance markets under-report losses in developing countries, especially those sustained by the poor. This is because loss claims reflect the value of the assets and the wealth of those affected. When tropical cyclones sweep across Florida, they hit one of the world's prime real estate locations, with properties protected by high levels of insurance coverage. When the same cyclones hit slums in Haiti or Guatemala, the market value is lower and the real estate of the poor is largely uninsured.

Is climate change implicated in the increase in climate disasters? Direct attribution is impossible. Every weather event is the product of random forces and systemic factors. If Hurricane Katrina had stayed out at sea it would have been just another powerful tropical cyclone. However, climate change is creating systemic conditions for more extreme weather events. All hurricanes gather their strength from the heat of the oceans—and the world's oceans are warming as a result of climate change. More intense storms with higher peak wind speeds and heavier precipitation are a predictable outcome. Similarly, while individual droughts in sub-Saharan Africa cannot be directly attributed

Figure 2.3 **Climate disasters are driving up insured losses**



Source: ABI 2005b.

to climate change, climate models predict systemic decreases in rainfall in sub-tropical areas—over 20 percent in some regions.

The precise role of climate change in driving up the number of people affected by climate disaster is also open to debate. Social factors have clearly contributed. Population growth, the expansion of human settlements in hazardous areas—for example, urban slums perched on fragile hillsides and villages located in flood zones—and ecological stress have all played a role in adding to risk exposure. However, climate hazards have also increased. The record shows that droughts in sub-Saharan Africa have become more frequent and protracted. Tropical storms have increased in intensity. Climate change may not provide a full explanation—but it is heavily implicated.[15]

Debates over attribution will continue. As shown in chapter 1, climate science does not provide certainties. However, uncertainty does not constitute a case for inaction. The global insurance industry has been forced into a radical reappraisal of the implications of climate risk for its business models (box 2.2). Across the world, people are being forced to adapt to emerging climate risks in their everyday lives. For small-scale farmers, urban slum dwellers and people living in low-lying coastal areas these risks threaten to become a powerful obstacle to human development.

Risk and vulnerability

Climate change scenarios provide a framework for identifying structural shifts in weather systems. How those shifts are transmitted through to human development outcomes is conditioned by the interplay of risk and vulnerability.

Risk affects everyone. Individuals, families and communities are constantly exposed to risks that can threaten their well-being. Ill-health, unemployment, violent crime, or a sudden change in market conditions can, in principle, affect anyone. Climate generates a distinctive set of risks. Droughts, floods, storms and other events have the potential to disrupt people's lives, leading to losses of income, assets and opportunities. Climate risks are not equally distributed, but they are widely disbursed.

Vulnerability is different from risk. The etymological root of the word is the Latin verb 'to wound'. Whereas risk is about exposure to external hazards over which people have limited control, vulnerability is a measure of capacity to manage such hazards without suffering a long-term, potentially irreversible loss of well-being.[16] The broad idea can be reduced to "some sense of insecurity, of potential harm people must feel wary of—'something bad' can happen and 'spell ruin'."[17]

Climate change threats illustrate the distinction between risk and vulnerability.[18] People living in the Ganges Delta and lower Manhattan share the flood risks associated with rising sea levels. They do not share the same vulnerabilities. The reason: the Ganges Delta is marked by high levels of poverty and low levels of infrastructural protection. When tropical cyclones and floods strike Manila in the Philippines, they expose the whole city to risks. However, the vulnerabilities are concentrated in the over-crowded, makeshift homes of the slums along the banks of the Pasig River, not in Manila's wealthier areas.[19]

The processes by which risk is converted into vulnerability in any country are shaped by the underlying state of human development,

Box 2.2 The global insurance industry—reassessing climate risk

Climate-related insurance claims have increased rapidly over the past two decades or more. While climate sceptics and some governments continue to question the links between climate change and climate disasters, many global insurance companies are drawing the opposite conclusion.

In the five years to 2004, insured losses from climate events averaged US$17 billion a year—a fivefold increase (in 2004 terms) over the four years to 1990. Climate-related insurance claims are rising more rapidly than population, income and insurance premiums, prompting the industry to reassess the viability of current business models.

That reassessment has taken different forms in different countries. In some cases the industry has emerged as a forceful advocate for the development of infrastructure aimed at reducing insured losses. In Canada and the United Kingdom, for example, insurance companies have led demands for increased public investment in storm and flood-defence systems, while also calling on Government to underwrite losses as an insurer of last resort.

In the United States, insurance companies were actively reviewing their exposure to climate risks even before Hurricane Katrina rewrote the history books in terms of storm damage costs. They have been putting caps on paid losses, shifting a greater part of the risk on to consumers, and withdrawing from high-risk areas. One of the side-effects of Hurricane Katrina has been to fuel the rise of catastrophic risk bonds, which transfer risk from insurers to capital markets: payments to bond holders cease in the event of a climate catastrophe. The market in 2006 stood at US$3.6 billion, compared with US$1 billion two years earlier.

Federal and state government insurance programmes have not been immune to climate-related pressures. The exposure of two major programmes—the National Flood Insurance Programme (exposure nearing US$1 trillion) and the Federal Crop Insurance Programme (exposure US$44 billion)—has prompted the Government Accountability Office to warn that "Climate change has implications for the fiscal health of the Federal Government."

Experience in developed country insurance markets highlights a wider problem. Climate change creates large uncertainties. Risk is a feature of all insurance markets. Premiums are calculated on the basis of risk assessment. With climate change, insurance claims are likely to rise over time. Based on one estimate from the Association of British Insurers, a doubling of CO_2 could increase insured losses from extreme storm events alone for the global industry by US$66 billion annually (at 2004 prices). The difficulty for the industry is that this trend will be punctuated by catastrophic events that will undermine pooled risk arrangements.

Source: ABI 2004, 2005b; Brieger, Fleck and Macdonald 2001; CEI 2005; GAO 2007; Mills 2006; Mills, Roth and Leomte 2005; Thorpe 2007.

including the inequalities in income, opportunity and political power that marginalize the poor. Developing countries and their poorest citizens are most vulnerable to climate change. High levels of economic dependence on agriculture, lower average incomes, already fragile ecological conditions, and location in tropical areas that face more extreme weather patterns, are all vulnerability factors. The following are among the factors that create a predisposition for the conversion of risk into vulnerability:

- *Poverty and low human development.* High concentrations of poverty among populations exposed to climate risk are a source of vulnerability. The 2.6 billion people—40 percent of the world's population—living on less than US$2 a day are intrinsically vulnerable because they have fewer resources with which to manage risks. Similarly, for the 22 countries with a combined population of 509 million people in the low human development category of the Human Development Index (HDI), even small increases in climate risk can lead to mass vulnerability. Across much of the developing world (including countries in the medium human development category) there is a two-way interaction between climate-related vulnerability, poverty and human development. Poor people are often malnourished partly because they live in areas marked by drought and low productivity; and they are vulnerable to climate risks because they are poor and malnourished. In some cases, that vulnerability is directly linked to climate shocks. Disaggregated HDI data for Kenya, for example, show a close fit between food emergencies linked to drought and districts where human development is low (table 2.1). In Ghana, half of children in the drought-prone northern region are malnourished, compared with 13 percent in Accra.[20]
- *Disparities in human development.* Inequalities within countries are another marker for vulnerability to climate shocks.

Table 2.1 Drought-related food emergencies and human development are closely linked in Kenya

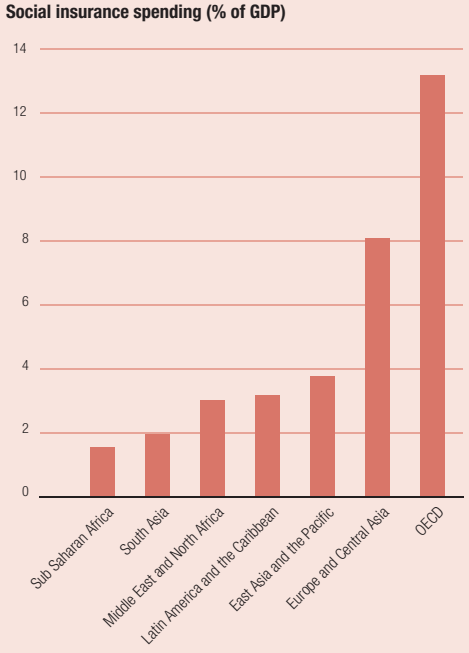
Kenyan districts	Human Development Index value 2005
Districts suffering food emergency (November 2005–October 2006)	
Garissa	0.267
Isiolo	0.580
Mandera	0.310
Masrabit	0.411
Mwingi	0.501
Samburu	0.347
Turkana	0.172
Wajir	0.256
Others	
Mombassa	0.769
Nairobi	0.773
Kenya national average	0.532

Source: UNDP 2006a; USAID FEWS NET 2007.

One recent quantitative assessment of the human impacts of disasters has found that "countries with high levels of income inequality experience the effects of climate disasters more profoundly than more equal societies".[21] Average levels of human development can obscure high levels of deprivation. Guatemala, for example, is a medium human development country marked by large social disparities between indigenous and non-indigenous people. Malnutrition among indigenous people is twice as high as for non-indigenous people. When Hurricane Stan swept across the Western Highlands of Guatemala in 2005 its impact was felt most heavily by indigenous people, the majority of them subsistence farmers or agricultural labourers. Losses of basic grains, the depletion of food reserves and the collapse of employment opportunities magnified already severe levels of deprivation, with inequality acting as a barrier to early recovery.[22] Disparities in human development also expose vulnerable populations to climate risks in some of the world's richest countries. When Hurricane Katrina hit New Orleans, some of America's poorest communities were affected. Recovery was hampered by deep underlying inequalities (box 2.3).

- *Lack of climate-defence infrastructure.* Infrastructural disparities help to explain why similar climate impacts produce very different outcomes. The elaborate system of dykes in the Netherlands acts as a powerful buffer between risk and vulnerability. Flood defence systems, water infrastructure and early warning systems all reduce vulnerability. Japan faces a higher exposure to risks associated with cyclones and flooding than the Philippines. Yet between 2000 and 2004, average fatalities amounted to 711 in the Philippines and only 66 in Japan.[23]
- *Limited access to insurance.* Insurance can play an important role in enabling people to manage climate risks without having to reduce consumption or run down their assets. Private markets and public policy can play a role. Households in rich countries have access to private insurance to protect themselves against climate-related losses. Most poor households in developing countries do not. Social insurance is another buffer against vulnerability. It enables people to cope with risks without eroding long-term opportunities for human development. It can provide for people in old age, afford

Figure 2.4 Social insurance provision is far greater in rich countries



Source: World Bank 2006g.

Box 2.3 Hurricane Katrina—the social demographics of a disaster

When Hurricane Katrina breached the levees of New Orleans it caused human suffering and physical damage on a vast scale. As the flood waters receded, they revealed the acute vulnerabilities associated with high levels of pre-existing social inequality. Flood damage was superimposed on a divided city, just as climate change damage will be superimposed on a divided world. Two years after the tragedy, inequalities continue to hamper recovery.

Located on the Gulf Coast of the United States, New Orleans is in one of the world's high-risk hurricane zones. In August 2005 the flood defences mitigating that risk were overwhelmed, with tragic consequences. Hurricane Katrina claimed over 1,500 lives, displaced 780,000 people, destroyed or damaged 200,000 homes, crippled the city's infrastructure and traumatized its population.

The hurricane impacted on the lives of some of the poorest and most vulnerable people in the world's richest nation. Pre-Katrina child poverty rates in New Orleans were among the highest in the United States, with one in three living below the poverty line. Health provision was limited, with some 750,000 people lacking insurance coverage.

Hurricane Katrina selected its victims overwhelmingly from the most disadvantaged areas of the city. Poorer districts dominated by black communities bore the brunt. Flood damage interacted with deep racial inequalities (poverty rates among blacks three times higher than for whites). An estimated 75 percent of the population living in flooded neighbourhoods was black. The Lower Ninth Ward and the Desire/Florida communities, two of the poorest and most vulnerable in the city, were both totally devastated by Katrina.

Images of the human suffering in New Orleans were beamed around the world as the city became a magnet for international media attention. Yet as people sought to rebuild their lives after the cameras had departed, pre-hurricane inequalities emerged as a barrier to recovery.

The health sector provides a striking example. Many of the health facilities in the safety net system serving the poor were damaged by Hurricane Katrina, with the Charity Hospital, which provided most of the medical care for this group—emergency, acute and basic—still closed. While a special Medicaid waiver was introduced to provide temporary coverage for uninsured evacuees, eligibility rules limited entitlements for low-income households without children, leading to a large number of rejected claims. It took Congress and the Administration 6 months to authorize a US$2 billion provision for Medicaid to cover uninsured health costs.

Research conducted by the Kaiser Family Foundation 6 months after the storm revealed that many people had been unable to maintain pre-existing treatment or to access the care needed to deal with new conditions. In household interviews, over 88 percent of respondents identified the need for expanded and improved health provision as a vital challenge for the city. Two years on, that challenge remains.

Of the many factors blocking the social and economic recovery of New Orleans, the health care system may be the most important. Only one of the city's seven general hospitals is operating at its pre-hurricane level; two more are partially open, and four remain closed. The number of hospital beds in New Orleans has dropped by two-thirds. There are now 16,800 fewer medical jobs than before the storm, down 27 percent, in part because nurses and other workers are in short supply.

Two important lessons emerge from Hurricane Katrina that have a wider bearing on climate change strategies. The first is that high levels of poverty, marginalization and inequality create a predisposition for risk to convert into mass vulnerability. The second is that public policy matters. Policies that provide people with entitlements to health and housing provision can facilitate early recovery, while weak entitlements can have the opposite effect.

Poverty in New Orleans

People living in poverty, 2000 (%)	New Orleans	United States
Total population	28	12
Children 18 years and younger	38	18
Whites	12	9
African–Americans	35	25

Source: Perry et al. 2006.

Source: Perry et al. 2006; Rowland 2007; Turner and Zedlewski 2006; Urban Institute 2005.

protection during periods of sickness or unemployment, assist child development and protect basic nutrition. Countries vary widely in their support for social insurance (figure 2.4). Rich countries spend a greater share of their far higher average incomes on social insurance. In terms of global climate change risk management this means that there is an inverse relationship between vulnerability (which is concentrated in poor countries) and insurance (which is concentrated in rich countries).

Gender inequalities intersect with climate risks and vulnerabilities. Women's historic disadvantages—their limited access to resources, restricted rights, and a muted voice in shaping decisions—make them highly vulnerable to climate change. The nature of that vulnerability varies widely, cautioning against generalization. But climate change is likely to magnify existing

Special contribution **Climate change as a human rights issue**

For many generations, Inuit have closely observed the environment, accurately predicting the weather so as to allow safe travel on the sea ice. However our ability to read and predict weather patterns and conditions around us is now greatly challenged as a result of climate change. For decades, our hunters have reported melting permafrost, thinning ice, receding glaciers, new invasive species, rapid coastal erosion and dangerously unpredictable weather. From our far Northern perspective, we have observed that the global climate change debate too often focuses on economic and technical matters rather than on the human impacts and consequences of climate change. Inuit are already experiencing these impacts and will soon face dramatic social and cultural dislocation.

Climate change is our greatest challenge: overarching, complex and requiring immediate action. It also presents an opportunity to reconnect with each other as a shared humanity, despite our differences. With this in mind I decided to look at the international human rights regimes that are in place to protect peoples from cultural extinction—the very situation we Inuit could be facing. The question was always how can we bring some clarity of purpose and focus to a debate that seems always to be caught up in technical arguments and competing short term ideologies? I believe it is significant internationally for global climate change to be debated and examined in the arena of human rights. As Mary Robinson said "human rights and the environment are interdependent and interrelated". That is why, together with 61 other Inuit, I worked to launch the Climate Change Human Rights Petition in December 2005.

In essence the petition states that governments should develop their economies using appropriate technologies that significantly limit greenhouse gas emissions. But we have also achieved much more than that.

Through this work we have made human faces—and our fates—the centre of attention. We have changed the international discourse from dry technical discussions to debates about human values, human development and human rights. We have given United Nations conferences a heartbeat, a renewed sense of urgency. We did this by reminding people far away from the Arctic that we are all connected: that the Inuit hunters falling through the thinning ice are connected to the people facing the melting glaciers of the Himalayas and the flooding of the small island states; but that this is also connected to the way the world goes about its daily life in terms of the cars we drive, the industries we support and the policies we choose to make and enforce.

A brief window of opportunity still remains to save the Arctic and, ultimately, the planet. Coordinated action can still forestall the future projected in the Arctic Climate Impact Assessment. Nations can again come together, as we did in Montreal in 1987 and Stockholm in 2001. Already our ozone is mending; already the toxic chemicals that poisoned the Arctic are decreasing. Now the world's greatest emitters must make binding commitments to act. I only hope that nations take this opportunity to once more come together through the understanding of our connectivity and our shared atmosphere, ultimately our shared humanity.

Sheila Watt-Cloutier
Advocate for Arctic climate change

patterns of gender disadvantage. In the agricultural sector, rural women in developing countries are the primary producers of staple food, a sector that is highly exposed to the risks that come with drought and uncertain rainfall. In many countries, climate change means that women and young girls have to walk further to collect water, especially in the dry season. Moreover, women can be expected to contribute much of the labour that will go into coping with climate risks through soil and water conservation, the building of anti-flood embankments and increased off-farm employment. One corollary of gender vulnerability is the importance of women's participation in any planning process for adaptation to climate change.[24]

Climate change is also providing a reminder of the symbiotic relationship between human culture and ecological systems. This relationship is very evident in the Arctic, where some of the world's most fragile ecosystems are being affected by rapid warming. Indigenous people in the Arctic have become sentinels for a world undergoing climate change. As one of the leaders of the Inuit community has commented: "The Arctic is the world's climate change barometer. Inuit are the mercury in that barometer."[25] For Inuit people, business-as-usual warming will disrupt or even destroy a culture based on hunting and food sharing, as reduced sea ice causes the animals on which they depend to become less accessible, and possibly decline towards extinction. In December 2005, representatives of Inuit organizations submitted a petition to the Inter-American Commission on Human Rights, claiming that unrestricted emissions from the United States were violating the

human rights of the Inuit. The aim was not to seek damages but rather redress, in the form of leadership in mitigating dangerous climate change.

Low human development traps

Human development is about expanding freedom and choice. Climate-related risks force people into trade-offs that limit substantive freedom and erode choice. These trade-offs can constitute a one-way ticket into low human development traps—downward spirals of disadvantage that undermine opportunities.

Climate shocks affect livelihoods in many ways. They wipe out crops, reduce opportunities for employment, push up food prices and destroy property, confronting people with stark choices. Wealthy households can manage shocks by drawing upon private insurance, using their savings, or trading in some of their assets. They are able to protect their current consumption—'consumption smoothing'—without running down their productive capacities or eroding their human capabilities. The poor have fewer options.

With limited access to formal insurance, low income and meagre assets, poor households have to adapt to climate shocks under more constrained conditions. In an effort to protect current consumption, they are often forced to sell productive assets, compromising future income generation. When incomes fall from already low levels, they may have no choice but to reduce the number of meals they eat, cut spending on health, or withdraw their children from school to increase labour supply. The coping strategies vary. However, the forced trade-offs that follow climate shocks can rapidly erode human capabilities, setting in train cycles of deprivation.

Poor households are not passive in the face of climate risks. Lacking access to formal insurance, they develop self-insurance mechanisms. One of these mechanisms is to build up assets—such as livestock—during 'normal' times for sale in the event of a crisis. Another is to invest household resources in disaster prevention. Household surveys in flood-prone urban slums in El Salvador record families spending up to 9 percent of their income on strengthening their homes against floods, while also using family labour to build retaining walls and maintain drainage channels.[26] Diversification of production and income sources is another form of self-insurance. For example, rural households seek to reduce their risk exposure by inter-cropping food staples and cash crops, and by engaging in petty trade. The problem is that self-insurance mechanisms often break down in the face of severe and recurrent climate shocks.

Research points to four broad channels or 'risk multipliers' through which climate shocks can undermine human development: 'before-the-event' losses in productivity, early coping costs, asset erosion of physical capital and asset erosion of human opportunities.

'Before-the-event' losses in productivity

Not all of the human development costs of climate shocks happen after the event. For people with precarious livelihoods in areas of climate variability, uninsured risk is a powerful impediment to increased productivity. With less capacity to manage risk, the poor face barriers to engage in higher-return but higher-risk investment. In effect, they are excluded from opportunities to produce their way out of poverty.

It is sometimes argued that the poor are poor because they are less 'entrepreneurial' and choose to avoid risky investments. The fallacy in this view lies in confusion between risk aversion and innovative capacity. As households move closer to extreme poverty they become risk averse for a very good reason: adverse outcomes can affect life chances at many levels. Operating without formal insurance in areas of high risk exposure—such as floodplains, drought-prone regions or fragile hillsides—poor households rationally choose to forego potentially higher return investments in the interests of household security. Farmers may be forced to make production decisions that are less sensitive to rainfall variation, but also less profitable.

Research in Indian villages in the 1990s found that even slight variations in rainfall timing could reduce farm profits for the poorest quartile of respondents by one-third, while

Climate-related risks force people into trade-offs that limit substantive freedom and erode choice

having a negligible impact on profitability for the richest quartile. Faced with high risk, poor farmers tended to over-insure: production decisions led to average profits that were lower than they could have been in an insured risk environment.[27] In Tanzania, village-level research found poor farmers specializing in the production of drought-resistant crops—like sorghum and cassava—which provide more food security but a lower financial return. The crop portfolio of the wealthiest quintiles yielded 25 percent more than that of the poorest quintile.[28]

This is part of a far wider pattern of de facto risk insurance that, interacting with other factors, increases inequality and locks poor households into low-return systems of production.[29] As climate change gathers pace, agricultural production in many developing countries will become riskier and less profitable (see section on Agriculture and food security below). With three-quarters of the world's poor dependent on agriculture, this has important implications for global poverty reduction efforts.

It is not just the world's poor that will have to adjust to new climate patterns. Agricultural producers in rich countries will also have to deal with the consequences, however, the risks are less severe, and they are heavily mitigated through large-scale subsidies—around US$225 billion in OECD countries in 2005—and public support for private insurance.[30] In the United States, Federal Government insurance payments for crop damage averaged US$4 billion a year from 2002 to 2005. The combination of subsidies and insurance enables producers in developed countries to undertake higher-risk investments to obtain higher returns than would occur under market conditions.[31]

Table 2.2 **Drought in Malawi—how the poor cope**

Behaviours adopted to cope with drought, 1999 (% of people)	Blantyre Town (%)	Rural Zomba (%)
Dietary adjustments		
• Substituted meat for vegetables	73	93
• Ate smaller portions to make meals last longer	47	91
• Reduced number of meals per day	46	91
• Ate different foods, such as cassava instead of maize	41	89
Expenditure reduction		
• Bought less firewood or paraffin	63	83
• Bought less fertilizer	38	33
Cash generation for food		
• Depleted savings	35	0
• Borrowed money	36	7
• Searched for casual labour *(ganyu)* for cash and food	19	59
• Sold livestock and poultry	17	15
• Sold household items and clothes	11	6
• Sent children to look for money	10	0

Source: Devereux 1999.

The human costs of 'coping'

The inability of poor households to cope with climate shocks is reflected in the immediate human impacts, and in increasing poverty. Droughts provide a potent example.

When rains fail the ripple effects are transmitted across many areas. Losses in production can create food shortages, push up prices, undermine employment, and depress agricultural wages. The impacts are reflected in coping strategies that range from reduced nutrition to the sale of assets (table 2.2). In Malawi, the 2002 drought left nearly 5 million people in need of emergency food aid. Long before the aid arrived, households had been forced to resort to extreme survival measures, including such activities as theft and prostitution.[32] The acute vulnerabilities that can be triggered by climate shocks in countries at low levels of human development were powerfully demonstrated in the 2005 food security crisis in Niger (box 2.4).

Droughts are often reported as short term, single events. That practice obscures some important impacts in countries where multiple or sequential droughts create repeated shocks over several years. Research in Ethiopia illustrates the point. The country has experienced at least five major national droughts since 1980, along with literally dozens of local droughts. Cycles of drought create poverty traps for many households, constantly thwarting efforts to build up assets and increase income. Survey data show that between 1999 and 2004 more than half of all households in the country experienced at least one major drought shock.[33] These shocks are a major cause of transient poverty: had households been able to smooth consumption, then poverty in 2004 would

have been at least 14% lower (table 2.3)—a figure that translates into 11 million fewer people below the poverty line.[34]

The human impacts of current climate shocks provide a widely ignored backdrop for understanding the human development implications of climate change. Malnutrition levels rise and people get locked into poverty traps. If climate change scenarios predicting more frequent and more intense droughts and floods are correct, the consequences could be large and rapid reversals in human development in the countries affected.

Table 2.3 The impact of drought shocks in Ethiopia

	People in poverty (%)
Observed poverty	47.3
Predicted poverty with no drought shocks	33.1
Predicted poverty with no shocks of any kind	29.4

Source: Dercon 2004.

Asset erosion—physical capital

Climate shocks can have devastating consequences for household assets and savings. Assets such as live animals represent something more than a safety net for coping with climate shocks. They provide people with a productive resource, nutrition, collateral for credit, and a source of income to meet health and education costs, while also providing security in the event of crop failure. Their loss increases future vulnerability.

Climate shocks create a distinctive threat to coping strategies. Unlike, say, ill-health, many climate shocks are covariate: that is, they affect entire communities. If all affected households sell their assets at the same time in order to protect consumption, asset prices can be expected to fall. The resulting loss of value can rapidly and severely undermine coping strategies, reinforcing wider inequalities in the process.

Research on the 1999/2000 drought in Ethiopia illustrates this point. The disaster began with a failure of the short or *belg* rains,

Box 2.4 Drought and food insecurity in Niger

Niger is one of the poorest countries in the world. It ranks close to bottom of the HDI, with a life expectancy of nearly 56 years, 40 percent of children having low weight for their age in an average year, and more than one in five children dying before their fifth birthday. Vulnerability to climate shocks in Niger is linked to several factors, including widespread poverty, high levels of malnutrition, precarious food security in 'normal' years, limited health coverage and agricultural production systems that have to cope with uncertain rainfall. During 2004 and 2005 the implications of these underlying vulnerabilities were powerfully demonstrated by a climate shock, with an early end to rains and widespread locust damage.

Agricultural production was immediately affected. Output fell sharply, creating a cereals deficit of 223,000 tonnes. Prices of sorghum and millet rose 80 percent above the 5-year average. In addition to high cereal prices, deteriorating livestock conditions deprived household of a key source of income and risk insurance. The loss of pasture and nearly 40 percent of the fodder crop, along with rising animal feed prices and 'distress sales', pushed down livestock prices, depriving households of a key source of income and risk insurance. With vulnerable households trying to sell under-nourished animals for income to buy cereals, the drop in prices adversely affected their food security and terms of trade.

By the middle of 2005 around 56 zones across the country were facing food security risks. Some 2.5 million people—around a fifth of the country's population—required emergency food assistance. Twelve zones in regions such as Maradi, Tahou and Zinder were categorized as 'extremely critical', meaning that people were reducing the number of meals eaten each day, consuming wild roots and berries, and selling female cattle and production equipment. The crisis in agriculture led to severe human costs, including:

- Migration to neighbouring countries and less critically affected zones.
- In 2005 Médecins Sans Frontières (MSF) re-reported an acute malnutrition rate of 19 percent among children aged 6–59 months in Maradi and Tahoua, representing a significant deterioration over average levels. MSF also reported a fourfold increase in the number of children suffering from severe malnutrition in therapeutic feeding centres.
- USAID survey team reported women spending entire days collecting *anza*, a wild food.

In some respects, Niger's low level of human development makes the country an extreme case. However, developments during 2005 demonstrated in stark fashion the mechanisms through which increased climate-related risk can disrupt coping strategies and create extensive vulnerabilities.

Source: Chen and Meisel 2006; Mousseau and Mittal 2006; MSF 2005; Seck 2007a.

The trade-offs forced upon people by climate shocks reinforce and perpetuate wider inequalities based on income, gender and other disparities

which can fall between February and April. This frustrated farmers' attempts to plough and sow crops. Reduced rainfall during the long rainy season (the June–September *meher* rains) caused widespread crop failure. When the subsequent *belg* season in early 2000 also saw poor rainfall, the result was a major food security crisis. Distress sales of assets—mainly livestock—began early and continued for 30 months. By the end of 1999, livestock sellers were receiving less than half the pre-drought price, constituting a huge loss of capital. However, not all farmers adopted the same coping strategy. The top two quartiles, with far more cattle, sold animals early in a classic 'consumption smoothing' pattern, trading in their insurance risk premium in order to maintain access to food. In contrast, the lowest two quartiles stubbornly held on to their small number of animals, with only small decreases in livestock ownership until the end of the drought period. The reason: their animals were a vital productive resource for ploughing. In effect, the rich were able to smooth consumption without detrimentally eroding their productive assets, whereas the poor were forced to choose between the two.[35]

Agropastoral and pastoral households, which are even more reliant on livestock for their livelihoods, also suffer severe asset losses during droughts. As experience in Ethiopia has repeatedly shown, the consequences are likely to include adverse impacts for their terms of trade, with livestock prices falling sharply relative to cereal prices.

Another example comes from Honduras. In 1998 Hurricane Mitch cut a wide path of destruction across the country. In this case, the poor were forced to sell a far greater share of their assets than wealthier households in order to cope with a steep increase in poverty. By running down the productive assets of the poor, the climate shock in this case created conditions for an increase in future inequalities (box 2.5).

Asset erosion—human opportunities

Media images of human suffering during climate shocks do not capture the damaging trade-offs into which poor households are forced. When droughts, floods, storms and other climate events disrupt production, cut income and erode assets, the poor face a stark choice: they must make up income losses or cut spending. Whatever the choice, the consequences are long-term costs that can jeopardize human development prospects. The trade-offs forced upon people by climate shocks reinforce and perpetuate wider inequalities based on income, gender and other disparities. Some examples:

- *Nutrition.* Climate shocks such as drought and floods can cause grave setbacks in nutritional status as food availability declines, prices rise and employment opportunities shrink. Deteriorating nutrition provides the most telling evidence that coping strategies are failing. The drought that swept across large areas of eastern Africa in 2005 illustrates the point. In Kenya, it put the lives of an estimated 3.3 million people in 26 districts at risk of starvation. In Kajiado, the worst affected district, the cumulative effect of the two poor rainy seasons in 2003 and the total failure of rains in 2004 almost completely wiped out production. Particularly, decline in the production of rainfed crops such as maize and beans harmed both people's diet and their purchasing power. Health centres in the district reported an increase in malnutrition, with 30 percent of children seeking medical assistance found to be underweight compared to 6 percent in normal years.[36] In some cases, the trade-offs between consumption and survival can exacerbate gender bias in nutrition. Research in India has found that girls' nutrition suffers most during periods of low consumption and rising food prices, and that rainfall shortages are more strongly associated with deaths among girls than boys.[37]
- *Education.* For the poorest households, increasing labour supply can mean transferring children from classrooms into the labour market. Even in 'normal' years, poor households are often forced to resort to child labour, for example during the lean season before harvests. Droughts and floods

intensify these pressures. In Ethiopia and Malawi, children are routinely taken out of school to engage in income-generating activities. In Bangladesh and India, children in poor households work on farms, tend cattle or engage in other tasks in exchange for food during periods of stress. In Nicaragua in the aftermath of Hurricane Mitch, the proportion of children working rather than attending school increased from 7.5 to 15.6 percent in affected households.[38] It is not only low-income countries that are affected. Household research in Mexico covering the period 1998–2000 shows an increase in child labour in response to drought.

- *Health.* Climate shocks are a potent threat to the poor's most valuable assets—their health and their labour. Deteriorating nutrition and falling incomes generate a twin threat: increased vulnerability to illness and fewer resources for medical treatment. Droughts and floods are often catalysts for wide-ranging health problems, including an increase in diarrhoea among children, cholera, skin problems and acute under-nutrition. Meanwhile, capacity to treat old problems and cope with new ones is hampered by increased poverty. Research for this Report shows that in Central Mexico during the period 1998 to 2000, children under five saw their chances of falling sick increasing when they suffered a weather shock: the probability of illness increased by 16 percent with droughts and by 41 percent with floods.[39] During the 2002 food crisis in southern Africa, over half of households in Lesotho and Swaziland reported reduced health spending.[40] Reduced or delayed treatment of diseases is an enforced choice that can have fatal consequences.

Forced trade-offs in areas such as nutrition, education and health have consequences that

Climate shocks are a potent threat to the poor's most valuable assets—their health and their labour

Box 2.5 Distress sales in Honduras

Climate change will bring with it more intense tropical storms as sea temperatures rise. The incremental risks will be borne across societies. However, poor households with limited risk management capacity will suffer the most. Evidence from Central America, which will be one of the worst affected regions, shows how storms can erode assets and exacerbate inequality.

In contrast to droughts, which emerge as 'slow-fuse' crises over months, storms create instantaneous effects. When Hurricane Mitch tore into Honduras in 1998 it had an immediate and devastating impact. Data collected shortly after the hurricane showed that poor rural households lost 30–40 percent of their income from crop production. Poverty increased by 8 percent, from 69 to 77 percent at a national level. Low-income households also lost on average 15–20 percent of their productive assets, compromising their prospects for recovery.

Some 30 months after Hurricane Mitch a household survey provided insights into asset management strategies in a distress coping environment. Almost half of all households reported a loss of productive assets. Not surprisingly, especially in a highly unequal country like Honduras, the value of the loss increased with wealth: the average pre-Mitch asset value reported by the wealthiest quartile was 11 times greater than for the poorest quartile. However, the poorest quartile lost around one-third of the value of their assets, compared with 7 percent for the wealthiest quartile (see table).

Source: Carter et al. 2005; Morris et al. 2001.

In the reconstruction effort, average aid to the richest 25 percent amounted to US$320 per household—slightly more than double the level for the poorest quartile.

Detailed analysis of post-shock asset recovery has drawn attention to the way in which Hurricane Mitch has reinforced asset-based inequality. When asset value growth rates over the two-and-a-half years after Mitch were compared with the predicted trend based on pre-Mitch data, it emerged that, while both rich and poor were rebuilding their asset base, the net growth rate for the poorest quartile was 48 percent below the predicted pre-Mitch trend, whereas for the richest quartile it was only 14 percent below.

The rise in asset inequality has important implications. Honduras is one of the most unequal countries in the world, with a Gini index for income distribution of 54. The poorest 20 percent account for 3 percent of national income. Asset loss among the poor will translate into diminished opportunities for investment, increased vulnerability and rising income inequality in the future.

Hurricane Mitch devastated the assets of the poor

	Poorest 25%	Second 25%	Third 25%	Wealthiest 25%
Share of assets lost as a result of Hurricane Mitch (%)	31.1	13.9	12.2	7.5

Source: Carter et al. 2005.

extend far into the future. Detailed household survey analysis in Zimbabwe demonstrates the longevity of human development impacts linked to climate shocks. Taking a group of children that were aged 1–2 years during a series of droughts between 1982 and 1984, researchers interviewed the same children 13–16 years later. They found that the drought had reduced average stature by 2.3 centimetres, delayed the start of school and resulted in a loss of 0.4 years of schooling. The education losses translated into a 14 percent loss of lifetime earnings. Impacts in Zimbabwe were most severe among children in households with few livestock—the main self-insurance asset for smoothing consumption.[41]

Caution must be exercised in interpreting results from one specific case. But the Zimbabwe experience demonstrates the transmission mechanisms from climate shocks through nutrition, stunting and educational deprivation into long-run human development losses. Evidence from other countries confirms the presence and the durability of these mechanisms. When Bangladesh was hit by a devastating flood in 1998, the poorest households were forced into coping strategies that led to long-term losses in nutrition and health. Today many adults are living with the consequences of the deprivation they suffered as children in the immediate aftermath of the flood (box 2.6).

Box 2.6 The 'flood of the century' in Bangladesh

Flooding is a normal part of the ecology of Bangladesh. With climate change, 'abnormal' flooding is likely to become a standing feature of the future ecology. Experience following the flood event of 1998—dubbed the 'flood of the century'—highlights the danger that increased flooding will give rise to long term human development setbacks.

The 1998 flood was an extreme event. In a normal year, around a quarter of the country experiences inundation. At its peak, the 1998 flood covered two-thirds of the country. Over 1,000 people died and 30 million were made homeless. Around 10 percent of the country's total rice crop was lost. With the duration of the flood preventing replanting, tens of millions of households faced a food security crisis.

Large-scale food imports and government food aid transfers averted a humanitarian catastrophe. However, they failed to avert some major human development setbacks. The proportion of children suffering malnutrition doubled after the flood. Fifteen months after the flood, 40 percent of the children with poor nutritional status at the time of the flood had still not regained even the poor level of nutrition they had prior to the flood.

Households adjusted to the floods in several ways. Reduced spending, asset sales and increased borrowing all featured. Poor households were more likely both to sell assets and to take on debts. Fifteen months after the floods had receded, household debt for the poorest 40 percent averaged 150 percent of monthly expenditure—twice the pre-flood level.

Management of the 1998 floods is sometimes seen as a success story in disaster management. To the extent that an even larger loss of life was averted, that perception is partially justified. However, the flood had long term negative impacts, notably on the nutritional status of already malnourished children. The affected children may never be in a position to recover from the consequences. Poor households suffered in the short term through reduced consumption and increased illness, and through having to take on high levels of household debt—a strategy that may have added to vulnerability.

Source: del Ninno and Smith 2003; Mallick et al. 2005.

From climate shocks today to deprivation tomorrow—low human development traps in operation

The idea that a single external shock can have permanent effects provides a link from climate shocks—and climate change—to the relationship between risk and vulnerability set out in this chapter. The direct and immediate impact of droughts, hurricanes, floods and other climate shocks can be ghastly. But the after-shocks interact with wider forces that hold back the development of human capabilities.

These after-shocks can be understood through a poverty trap analogy. Economists have long recognized the presence of poverty traps in the lives of the poor. While there are many versions of the poverty trap, they tend to focus on income and investment. In some accounts, poverty is seen as the self-sustaining outcome of credit constraints that limit the capacity of the poor to invest.[42] Other accounts point to a self-reinforcing cycle of low productivity, low income, low savings and low investments. Linked to these are poor health and limited opportunities for education, which in turn restrict opportunities for raising income and productivity.

When climate disasters strike, some households are rapidly able to restore their livelihoods and rebuild their assets. For other households, the recovery process is slower. For some—especially the poorest—rebuilding may not be possible at all. Poverty traps can be thought of as a minimum threshold for assets or income, below which people are

unable to build productive assets, educate their children, improve their health and nutrition and increase income over time.[43] People above that threshold are able to manage risks in ways that do not lead to downward cycles of poverty and vulnerability. People below it are unable to reach the critical point beyond which they can escape the gravitational pull of poverty.

Analysis of income poverty traps has drawn attention to the processes by which deprivation is transmitted through time. By the same token, it has underplayed the importance of human capabilities—the wider set of attributes that determine the choices open to people. Shifting the focus towards capability does not mean ignoring the role of income. Low income is clearly a major cause of human deprivation. However, limited income is not the only thing that holds back the development of capabilities. Exclusion from opportunities for basic education, health and nutrition are sources of capability deprivation. In turn, these are linked to lack of progress in other dimensions, including the ability of people to participate in decision-making and to assert their human rights.

Like poverty traps, low human development traps occur when people are unable to pass a threshold beyond which they can engineer a virtuous circle of capability expansion. Climate shocks are among the many external factors that sustain such traps over time. They interact with other events—ill-health, unemployment, conflict and disruptions in markets. While these are important, climate shocks are among the most potent forces sustaining low human development traps.

Research carried out for this Report provides evidence of low human development traps in operation. In order to track the impact of climate shocks across time in the lives of those affected, we developed an econometric model to explore microlevel household survey data (*Technical Note 2*). We looked at specific human development outcomes associated with an identified climate shock. What difference does it make to the nutritional status of children if they were born during a drought? Using our model we addressed that question for several countries that face recurrent droughts. The results demonstrate the damaging impact of drought on the life chances of affected children:

- In Ethiopia, children aged five or less are 36 percent more likely to be malnourished and 41 percent more likely to be stunted if they were born during a drought year and affected by it. This translates into some 2 million 'additional' malnourished children.
- For Kenya, being born in a drought year increases the likelihood of children being malnourished by 50 percent.
- In Niger, children aged two or under who were born during a drought year and were affected by it are 72 percent more likely to be stunted, pointing to the rapid conversion of droughts into severe nutritional deficits.

These findings have important implications in the context of climate change. Most obviously, they demonstrate that the inability of poor households to cope with 'current' climate shocks is already a major source of human capability erosion. Malnutrition is not an affliction that is shaken off when the rains return or the flood waters recede. It creates cycles of disadvantage that children will carry with them throughout their lives. Indian women born during a drought or a flood in the 1970s were 19 percent less likely to ever attend primary school, when compared with women the same age who were not affected by natural disasters. The incremental risks associated with climate change have the potential to reinforce these cycles of disadvantage.

We stress the word 'potential'. Not every drought is the prelude to famine, malnutrition or educational privation. And not every climate shock gives rise to the distress sale of assets, long-run increases in vulnerability or the spread of low human development traps. This is an area in which public policies and public institutions make a difference. Governments can play a critical role in creating mechanisms that build resilience, support pro-poor risk management and reduce vulnerability. Policies in these areas can create an enabling environment for human development. With climate change, international cooperation on adaptation is a key condition for scaling-up these policies to meet incremental risks—an issue to which we return in chapter 4.

Governments can play a critical role in creating mechanisms that build resilience, support pro-poor risk management and reduce vulnerability

Developing countries are likely to become more dependent on imports from the rich world, with their farmers losing market shares in agricultural trade

2.2 Looking ahead—old problems and new climate change risks

"Prediction is very difficult, especially if it's about the future," commented the Danish physicist and Nobel laureate Niels Bohr. The observation applies with special force to climate. However, while specific events are uncertain, changes in average conditions associated with climate change can be predicted.

The IPCC's Fourth Assessment Report provides a best-estimate set of projections for future climate. These projections are not weather forecasts for individual countries. What they offer is a range of probabilities for broad changes in climate patterns. The underlying story has important implications for human development. Over the decades ahead there will be a steady increase in human exposure to such events as droughts, floods and storms. Extreme weather events will become more frequent and more intense, with less certainty and predictability in the timing of monsoons and rainfall.

In this section we provide an overview of the links from the IPCC's projections to human development outcomes.[44] We focus on 'likely' and 'very likely' outcomes for climate, defined respectively as results with an occurrence probability in excess of 66 and 90 percent.[45] While these outcomes relate only to average global and regional conditions, they help to identify emerging sources of risk and vulnerability.

Agricultural production and food security

IPCC projection: Increases in precipitation in high latitudes and decreases in sub-tropical latitudes, continuing the current pattern of drying in some regions. Warming is likely to be above the global average throughout sub-Saharan Africa, eastern Asia and South Asia. In many water-scarce regions, climate change is expected to further reduce water availability through increased frequency of droughts, increased evaporation and changes in patterns of rainfall and runoff.[46]

Human development projection: Major losses in agricultural production leading to increased malnutrition and reduced opportunities for poverty reduction. Overall, climate change will lower the incomes and reduce the opportunities of vulnerable populations. By 2080, the number of additional people at risk of hunger could reach 600 million—twice the number of people living in poverty in sub-Saharan Africa today.[47]

Global assessments of the impact of climate change on agriculture obscure very large variations across and even within countries. In broad terms, climate change will increase the risks to and reduce the productivity of developing country agriculture. In contrast, production could be boosted in developed countries, so that the distribution of world food production may shift. Developing countries are likely to become more dependent on imports from the rich world, with their farmers losing market shares in agricultural trade.[48]

Emerging patterns of climate change risk in agriculture will have important implications for human development. Around three in every four people in the world living on less than US$1 a day reside in rural areas. Their livelihoods depend on smallholder agriculture, farm employment, or pastoralism.[49] The same constituency also accounts for most of the 800 million people in the world who are malnourished. Climate change impacts on agriculture will thus have important multiplier effects. Agricultural production and employment underpin many national economies (table 2.4). The agricultural sector accounts for over one-third of export earnings in around 50 developing countries and for almost half of employment in the developing world.[50] In sub-Saharan Africa in particular, economic growth rates are closely tied to rainfall, as demonstrated by the experience of Ethiopia (figure 2.5). Moreover, every US$1 generated in agriculture in sub-Saharan Africa is estimated to generate up to US$3 in the non-agricultural sector.[51]

Climate modelling exercises point to very large changes in production patterns. One study has averaged out the findings of six such exercises, identifying changes in output potential for the 2080s.[52] The results paint a worrying picture. At global level, aggregate agricultural output potential will be relatively little affected by climate change. However, the average masks significant variations. By the 2080s, agricultural potential could increase by 8 percent in developed countries, primarily as a result of longer growing seasons, while in the developing world it could fall by 9 percent, with sub-Saharan Africa and Latin America projected to experience the greatest losses (figure 2.6).

Sub-Saharan Africa—a region at risk

As the world's poorest and most rainfall-dependent region, sub-Saharan Africa is a cause for special concern. Across the region, agricultural producers are operating with limited resources in fragile environments sensitive to even minor shifts in temperature and rainfall patterns. In dryland areas sophisticated intercropping systems—maize and beans, cowpea and sorghum, and millet and groundnut, for example—have been developed to manage risk and sustain livelihoods. Climate change poses a direct threat to these systems and to the livelihoods that they sustain.

Part of that threat comes from expansion of the area vulnerable to drought, as projected by the Hadley Centre for Climate Change (map 2.1). Arid and semi-arid areas are projected to increase by 60–90 million hectares. By 2090, in some regions, climate change has the potential to cause extreme damage. Southern Africa faces especially acute threats: yields from rainfed agriculture could be reduced by up to 50 percent between 2000 and 2020, according to the IPCC.[53]

Dryland agricultural systems will register some of the most damaging impacts from climate change. One study has looked at the potential implications for dryland areas in

Table 2.4 Agriculture plays a key role in developing regions

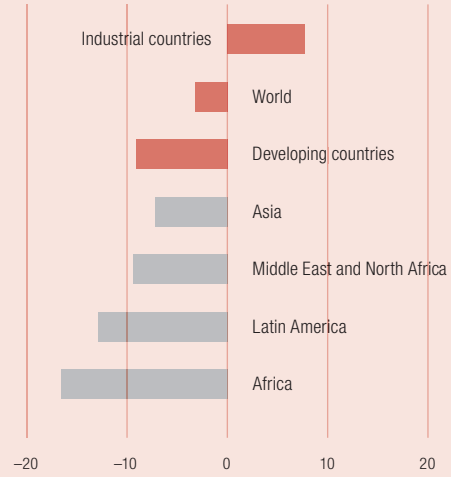
	Agricultural value added (% of GDP) 2005	Agricultural labour force (% of total labour force) 2004
Arab States	7	29
East Asia and the Pacific	10	58
Latin America and the Caribbean	7	18
South Asia	17	55
Sub-Saharan Africa	16	58

Source: Column 1: World Bank 2007d; column 2: WRI 2007b.

Figure 2.5 Income variability trails rainfall variability in Ethiopia

Source: World Bank 2006e.

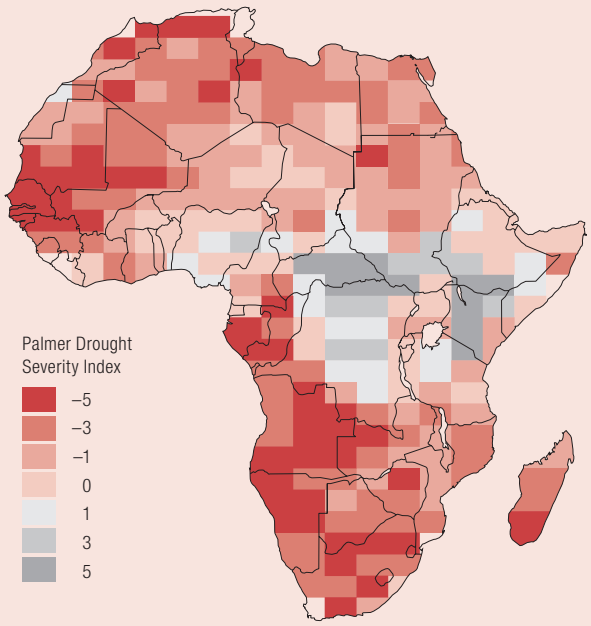
Figure 2.6 Climate change will hurt developing countries' agriculture



Source: Cline 2007.

Map 2.1 Drying out: Africa's drought area is expanding

Drought severity under IPCC scenario A2 (change relative to 2000 by 2090)



Note: The boundaries shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations.
IPCC scenarios describe plausible future patterns of population growth, economic growth, technological change and associated CO_2 emissions. The **A1 scenarios** assume rapid economic and population growth combined with reliance on fossil fuels (A1FI), non-fossil energy (A1T) or a combination (A1B). The **A2 scenario**, used here, assumes lower economic growth, less globalization and continued high population growth. A negative change in the Palmer Drought Severity Index, calculated based on precipitation and evaporation projections, implies more severe droughts.

Source: Met Office 2006.

sub-Saharan Africa of a 2.9°C increase in temperature, coupled with a 4 percent reduction in rainfall by 2060. The result: a reduction in revenue per hectare of about 25 percent by 2060. In 2003 prices, overall revenue losses would represent around US$26 billion in 2060 [54]—a figure in excess of bilateral aid to the region in 2005. More broadly, the danger is that extreme food insecurity episodes, such as those that have frequently affected countries like Malawi, will become more common (box 2.7).

Cash crop production in many countries could be compromised by climate change. With an increase of 2°C in average temperatures, it is projected that the land area available for growing coffee in Uganda will shrink.[55] This is a sector that accounts for a large share of cash income in rural areas and figures prominently in export earnings. In some cases, modelling exercises produce optimistic results that mask pessimistic processes. For example, in Kenya it would be possible to maintain tea production—but not in current locations. Production on Mount Kenya would have to move up to higher slopes currently occupied by forests, suggesting that environmental damage could be a corollary of sustained production.[56]

Climate change on the scale projected for sub-Saharan Africa will have consequences that extend far beyond agriculture. In some countries, there are very real dangers that changed climate patterns will become drivers for conflict. For example, climate models for Northern Kordofan in Sudan indicate that temperatures will rise by 1.5°C between 2030 and 2060, with rainfall declining by 5 percent. Possible impacts on agriculture include a 70 percent drop in yields of sorghum. This is against the backdrop of a long-term decline in rainfall that, coupled with overgrazing, has seen deserts encroach in some regions of Sudan by 100 kilometres over the past 40 years. The interaction of climate change with ongoing environmental degradation has the potential to exacerbate a wide range of conflicts, undermining efforts to build a basis for long-term peace and human security.[57]

The wider threats

These extreme threats facing sub-Saharan Africa should not distract from wider risks for human development. Climate change will have important but uncertain consequences for rainfall patterns across the developing world.

Large uncertainties surround the El Niño/Southern Oscillation (ENSO)—an ocean–atmosphere cycle that spans a third of the globe. In broad terms, El Niño increases the risk of drought across southern Africa and large areas of South and East Asia, while increasing hurricane activity in the Atlantic. Research in India has found evidence of links between El Niño and the timing of the monsoon, on which the viability of entire agricultural systems depends.[58] Even small changes in monsoon intensity and variability could have dramatic consequences for food security in South Asia.

Global projections of climate change can obscure important local effects. Consider the case of India. Some projections point to

Box 2.7 Climate change in Malawi—more of the same, and worse

Climate change models paint a bleak picture for Malawi. Global warming is projected to increase temperatures by 2–3°C by 2050, with a decline in rainfall and reduced water availability. The combination of higher temperatures and less rain will translate into a marked reduction in soil moisture, affecting the 90 percent of smallholder farmers who depend on rainfed production. Production potential for maize, the main smallholder food crop, which in a normal year is the source of three-quarters of calorie consumption, is projected to fall by over 10 percent.

It is hard to overstate the implications for human development. Climate change impacts will be superimposed on a country marked by high levels of vulnerability, including poor nutrition and among the world's most intense HIV/AIDS crisis: almost one million people are living with the disease. Poverty is endemic. Two in every three Malawians live below the national poverty line. The country ranks 164 out of the 177 countries measured in the HDI. Life expectancy has fallen to about 46 years.

Successive droughts and floods in recent years have demonstrated the added pressures that climate change could generate. In 2001/2002, the country suffered one of the worst famines in recent living memory as localized floods cut maize output by one-third. Between 500 and 1,000 people in the central and southern part of the country died during the disaster or in the immediate aftermath. Up to 20,000 are estimated to have died as an indirect result of associated malnutrition and disease. As maize prices rose, malnutrition increased: from 9 percent to 19 percent between December 2001 and March 2002 in the district of Salima.

The 2001/2002 drought undermined coping strategies. People were forced not just to cut back on meals, withdraw children from school, sell household goods and increase casual labour, but also to eat seeds that would have been planted and exchange productive assets for food. As a result, many farmers had no seed to plant in 2002. In 2005, the country was again in the grip of a crisis caused by drought, with more than 4.7 million people out of a population of over 13 million experiencing food shortages.

Climate change threatens to reinforce the already powerful cycles of deprivation created by drought and flood. Incremental risks will be superimposed upon a society marked by deep vulnerabilities. In a 'normal' year, two-thirds of households are unable to produce enough maize to cover household needs. Declining soil fertility, associated with limited access to fertilizer, credit and other inputs, has reduced maize production from 2.0 tonnes per hectare to 0.8 tonnes over the past two decades. Productivity losses linked to reduced rainfall will make a bad situation far worse.

Apart from its immediate consequences for health, HIV/AIDS has created new categories of vulnerable groups. These include households lacking adult labour or headed by elderly people or children, and households with sick family members unable to maintain production. Women are faced with the triple burden of agricultural production, caring for HIV/AID victims and orphans, and collecting water and firewood. Almost all HIV/AIDS-affected households covered in a survey of the Central region reported reduced agricultural production. HIV/AIDS-affected groups will be in the front line facing incremental climate change risks.

For a country like Malawi climate change has the potential to produce extreme setbacks for human development. Even very small increments to risk through climate change can be expected to create rapid downwards spirals. Some of the risks can be mitigated through better information, flood management infrastructure and drought-response measures. Social resilience has to be developed through social provision, welfare transfers and safety nets that raise the productivity of the most vulnerable households, empowering them to manage risk more effectively.

Source: Devereux 2002, 2006c; Menon 2007a; Phiri 2006; Republic of Malawi 2006.

substantial aggregate increases in rainfall for the country as a whole. However, more rain is likely to fall during intense monsoon periods in already rain-abundant parts of the country (creating increased risk of flooding), while other large areas will receive less rainfall. These include drought-prone areas in Andhra Pradesh, Gujarat, Madhya Pradesh and Rajasthan. Microlevel climate research for Andhra Pradesh shows temperatures rising by 3.5°C by 2050, leading to a decline of 8–9 percent in yields for water-intensive crops such as rice.[59]

Losses on this scale would represent a source of greatly increased vulnerability in rural livelihoods. Falling production would reduce the amount of food grown by households for their own consumption, cut supplies to local markets and diminish opportunities for employment. This is another area in which evidence from the past can cast light on future threats. In Andhra Pradesh, one survey covering eight districts in dryland areas found that droughts occurred on average once every 3–4 years, leading to losses in output value of 5–10 percent. This is enough to push many farmers below the poverty line. Models for farm income in India as a whole suggest that a 2–3.5°C temperature increase could be associated with a net farm revenue reduction of 9–25 percent.[60]

Losses of productivity linked to climate change will increase inequalities between rainfed and commercial producers, undermine livelihoods and add to pressures that are leading to forced migration

The implications of this projection should not be underestimated. While India is a high- growth economy, the benefits have been unequally shared and there is a large human development backlog. Around 28 percent of the population, some 320 million people, live below the poverty line, with three-quarters of the poor in rural areas. Unemployment among rural labourers, one of the poorest groups, is increasing, and almost half of rural children are underweight for their age.[61] Superimposing incremental climate change risks on this large human development deficit would compromise the ambition of 'inclusive growth' set out in India's Eleventh Five–Year Plan.

Projections for other countries in South Asia are no more encouraging:

- Climate scenario exercises for Bangladesh suggest that a 4°C temperature increase could reduce rice production by 30 percent and wheat production by 50 percent.[62]
- In Pakistan, climate models simulate agricultural yield losses of 6–9 percent for wheat with a 1°C increase in temperature.[63]

National projections for climate change in other regions confirm potentially large-scale economic losses and damage to livelihoods. In Indonesia, climate models simulating the impact of temperature changes, soil moisture content and rainfall on agricultural productivity show a wide dispersion of results, with yields falling by 4 percent for rice and 50 percent for maize. Losses will be especially marked in coastal areas where agriculture is vulnerable to salt water incursion.[64]

In Latin America, smallholder agriculture is particularly vulnerable, partly because of limited access to irrigation and partly because maize, a staple across much of the region, is highly sensitive to climate. There is considerable uncertainty in climate model projections for crop production. However, recent models point to the following as plausible outcomes:

- Smallholder losses for maize yields averaging around 10 percent across the region, but rising to 25 percent for Brazil.[65]
- Losses for rainfed maize production will be far higher than for irrigated production with some models predicting losses of up to 60 percent for Mexico.[66]
- Increased soil erosion and desertification caused by increased rainfall and higher temperatures in southern Argentina, with heavy precipitation and increased exposure to flooding damaging production of soya in the central humid Pampas.[67]

Changes in agricultural production linked to climate change will have important implications for human development in Latin America. While agriculture accounts for a shrinking share of regional employment and GDP, it remains the source of livelihood for a large section of the poor. In Mexico, for example, around 2 million low-income producers depend on rainfed maize cultivation. Maize is the main food staple for producers in the 'poverty-belt' states of southern Mexico, such as Chiapas. Productivity in these states is currently around a third of the level in irrigated commercial agriculture, holding back poverty reduction efforts. Losses of productivity linked to climate change will increase inequalities between rainfed and commercial producers, undermine livelihoods and add to pressures that are leading to forced migration.

Water stress and scarcity

IPCC projection: Changing climate patterns will have important implications for water availability. It is very likely that mountain glaciers and snow cover will continue to retreat. With rising temperatures, changes in runoff patterns and increased water evaporation, climate change will have a marked impact on the distribution of the world's water—and on the timing of flows.

Human development projection: Large areas of the developing world face the imminent prospect of increased water stress. Flows of water for human settlements and agriculture are likely to decrease, adding to already acute pressures in water-stressed areas. Glacial melting poses distinctive human development threats. In the course of the 21st Century water supply stored in glaciers and snow cover will decline, posing immense risks for agriculture, the environment and human settlements. Water stress will figure

prominently in low human development traps, eroding the ecological resources on which the poor depend, and restricting options for employment and production.

Water is a source of life and livelihoods. As we showed in the *Human Development Report 2006,* it is vital to the health and well-being of households and an essential input into agriculture and other productive activities. Secure and sustainable access to water—water security in its broadest sense—is a condition for human development.

Climate change will be superimposed on wider pressures on water systems. Many river basins and other water sources are already being unsustainably 'mined'. Today, around 1.4 billion people live in 'closed' river basins where water use exceeds discharge levels, creating severe ecological damage. Symptoms of water stress include the collapse of river systems in northern China, rapidly falling groundwater levels in South Asia and the Middle East, and mounting conflicts over access to water.

Dangerous climate change will intensify many of these symptoms. Over the course of the 21st Century, it could transform the flows of water that sustain ecological systems, irrigated agriculture and supplies of household water. In a world that is already facing mounting pressure on water resources, climate change could add around 1.8 billion people to the population living in a water-scarce environment—defined in terms of a threshold of 1000 cubic metres per capita per annum—by 2080.[68]

Scenarios for the Middle East, already the world's most water-stressed region, point in the direction of increasing pressure. Nine out of fourteen countries in the region already have average per capita water availability below the water scarcity threshold. Decreased precipitation is projected for Egypt, Israel, Jordan, Lebanon and Palestine. Meanwhile, rising temperatures and changes in runoff patterns will influence the flow of rivers upon which countries in the region depend. The following are among the findings to emerge from national climate modelling exercises:

- In Lebanon, a 1.2°C increase in temperature is projected to decrease water availability by 15 percent because of changed runoff patterns and evaporation.[69]
- In North Africa even modest temperature increases could dramatically change water availability. For example, a 1°C increase could reduce water runoff in Morocco's Ouergha watershed by 10 percent by 2020. If the same results hold for other watersheds, the result would be equivalent to losing the water contained by one large dam each year.[70]
- Projections for Syria point to even deeper reductions: a 50 percent decline in renewable water availability by 2025 (based on 1997 levels).[71]

Climate change scenarios for water in the Middle East cannot be viewed in isolation. Rapid population growth, industrial development, urbanization and the need for irrigation water to feed a growing population are already placing immense pressure on water resources. The incremental effects of climate change will add to that pressure within countries, potentially giving rise to tensions over water flowing between countries. Access to the waters of the River Jordan, cross-border aquifers, and the River Nile could become flashpoints for political tensions in the absence of strengthened water-management systems.

Glaciers in retreat

Glacial melting poses threats to more than 40 percent of the world's population.[72] The precise timing and magnitude of these threats remains uncertain. However, they are not a distant prospect. Glaciers are already melting at an accelerating rate. That trend is unlikely to be reversed over the next two to three decades, even with urgent mitigation. Climate change scenarios point to increased flows in the short term, followed by long term drying.

The thousands of glaciers located across the 2,400 kilometres of the Himalayan range are at the epicentre of an emerging crisis. These glaciers form vast water banks. They store water and snow in the form of ice, building up stores during the winter and releasing them during the summer. The flow sustains river systems that are

Climate change will be superimposed on wider pressures on water systems. Many river basins and other water sources are already being unsustainably 'mined'

The past 25 years have seen some glacier systems in the tropics transformed. Their impending disappearance has potentially disastrous implications for economic growth and human development

the lifeblood of vast ecological and agricultural systems.

Himalayas is a Sanskrit word that translates as 'abode of snow'. Today the glacial abode, the largest mass of ice outside of the polar caps, is shrinking at a rate of 10–15 metres a year.[73] The evidence shows the pace of melting to be uneven. But the direction of change is clear.

At current rates two-thirds of China's glaciers—including Tien Shan—will disappear by 2060, with total melting by 2100.[74] The Gangotri glacier, one of the main water reservoirs for the 500 million people living in the Ganges basin, is shrinking by 23 metres a year. One recent study by the Indian Space Research Organisation, using satellite images and covering 466 glaciers, found a 20 percent reduction in size. Glaciers on the Qinghai–Tibet plateau, a barometer of world climate conditions and the source of the Yellow and Yangtze rivers, have been melting by 7 percent a year.[75] With any climate change scenario in excess of the 2°C dangerous climate change threshold, the rate of glacial retreat will accelerate.

Accelerated glacial melt creates some immediate human development risks. Avalanches and floods pose special risks to densely populated mountain regions. One of the countries facing severe risks today is Nepal, where glaciers are retreating at a rate of several metres each year. Lakes formed by melting glacier waters are expanding at an alarming rate—the Tsho Rolpa Lake being a case in point, having increased more than sevenfold in the last 50 years. A comprehensive assessment completed in 2001 identified 20 glacial lakes that could potentially burst their banks, with catastrophic consequences for people, agriculture and hydropower infrastructure, unless urgent action is taken. [76]

As glacial water banks are run down, water flows will diminish. Seven of Asia's great river systems—the Brahmaputra, the Ganges, the Huang He, the Indus, the Mekong, the Salween and the Yangtze—will be affected. These river systems provide water and sustain food supplies for over 2 billion people.[77]

- The flow of the Indus, which receives nearly 90 percent of its water from upper mountain catchments, could decline by as much as 70 percent by 2080.
- The Ganges could lose two-thirds of its July–September flow, causing water shortages for over 500 million people and one-third of India's irrigated land area.
- Projections for the Brahmaputra point to reduced flows of between 14 and 20 percent by 2050.
- In Central Asia, losses of glacial melt into the Amu Darya and Syr Darya rivers could restrict the flow of water for irrigation into Uzbekistan and Kazakhstan, and compromise plans to develop hydroelectric power in Kyrgyzstan.

Climate change scenarios for glacial melting will interact with already severe ecological problems and put pressure on water resources. In India, competition between industry and agriculture is creating tensions over the allocation of water between states. Reduced glacial flows will intensify those tensions. Northern China is already one of the world's most water-stressed regions. In parts of the Huai, Hai and Huang (Yellow) basins (the '3-H' river basins) current water extraction is 140 percent of renewable supply—a fact that explains the rapid shrinkage of major river systems and falling groundwater tables. Over the medium term, changed glacial melting patterns will add to that stress. In an area that is home to around half of China's 128 million rural poor, contains about 40 percent of the country's agricultural land area and accounts for one-third of GDP, this has serious implications for human development (box 2.8).[78]

Tropical glaciers are also shrinking

Tropical glaciers are retreating even more rapidly than those in the Himalayas. In the lifetime of a glacier, a quarter of a century represents the blink of an eye. But the past 25 years have seen some glacier systems in the tropics transformed. Their impending disappearance has potentially disastrous implications for economic growth and human development.

Surveys by geologists suggest that the rate at which Latin America's glaciers are retreating is increasing. There are 2,500 square kilometres of glaciers in the tropical

Box 2.8 Climate change and China's water crisis

Over the past two decades China has emerged as the manufacturing workshop of the world. Rapid economic growth has gone hand-in-hand with a steep decline in poverty and improving human development indicators. Yet China is highly vulnerable to climate change.

By 2020 average temperatures in China are projected to be between 1.1 and 2°C above 1961–1990 levels. In a country as vast as China, spanning several climatic zones, the effects will be complex and diverse. However, a National Climate Change Assessment predicts more droughts, spreading deserts and reduced water supplies. Projections for agriculture suggest that the production of rice, maize and wheat could fall by 10 percent by 2030, and by up to 37 percent during the second half of the century because of climate-related factors.

As in other countries, climate change in China will interact with underlying stresses. The river systems of northern China provide a powerful demonstration of the ecological pressures generated by rapid economic growth. The Hai, Huai and Huang (Yellow) River Basins (the 3-H river basins) supply just under half of China's population with water. With the growing demands of industry, urban centres and agriculture, water is being withdrawn from the basins at twice the rate of replenishment. The result: rivers that no longer reach the sea and sinking groundwater tables.

Any reduction in water flows through the 3-H basins could rapidly turn an ecological crisis into an outright social and economic disaster. Around one-third of China's GDP originates in the basins, along with a large share of its grain production. One in every two of the rural poor lives here—most of them directly dependent on agriculture. As drought, rising temperatures and reduced runoff under climate change take effect, an obvious danger is that the adjustment costs will be borne first by the poor.

In western China entire ecological systems are under threat. Projected temperature increases for this region are 1–2.5°C by 2050. The Qinghai–Tibet plateau covers a landmass the size of Western Europe and contains more than 45,000 glaciers. These glaciers are retreating at the dramatic rate of 131.4 square kilometres annually. On current trends, most will disappear altogether by the end of the century.

What is happening to China's glaciers constitutes a national ecological security crisis of the first order. In the short term, increased flows of water from ice melt are likely to lead to more flooding. In the long term, the retreat of the glaciers will deprive communities living in the mountains of their water and transform large swathes of China's environment. Desertification will gather pace as rising temperatures and unsustainable land-use practices continue to accelerate to soil erosion. Events such as the 13 major dust-storms recorded in 2005, one of which deposited 330,000 tonnes of sand in Beijing, will become more common. Meanwhile, flows into the Yangtze, the Yellow and other rivers that originate on the Qinghai–Tibet plateau will decline, adding to the stress on water-based ecological systems.

It is not only rural environments that stand to suffer. The city of Shanghai is particularly vulnerable to climate-related hazards. Located at the mouth of the Yangtze river, at an elevation of only 4 metres above sea level, the city faces acute flood risks. Summer typhoons, storm surges and excessive river runoff contribute to extreme flooding.

All of Shanghai's 18 million residents face the risk of flooding. Rising sea levels and increased storm surges have put the coastal city on the danger list. However, vulnerability is heavily concentrated among the estimated 3 million temporary residents who have migrated from rural areas. Living in transient encampments around construction sites or in flood-prone areas, and with limited rights and entitlements, this population is faced with a high exposure to risk with extreme vulnerability.

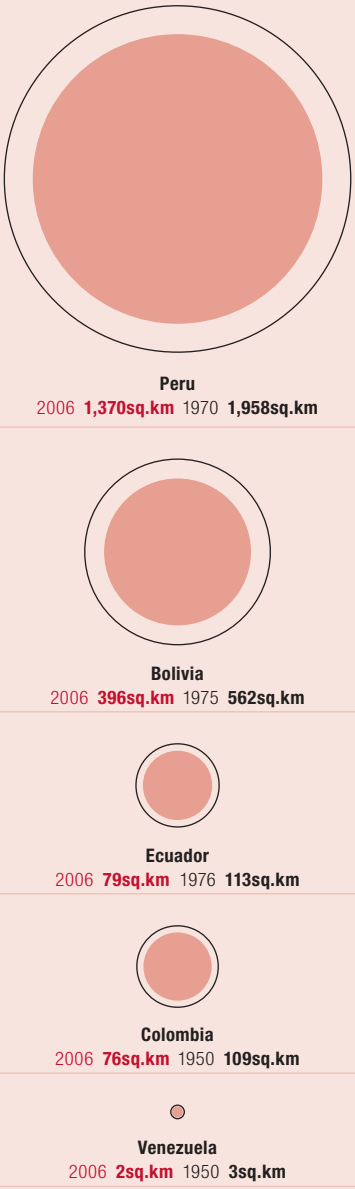
Source: Cai 2006; O'Brien and Leichenko 2007; People's Republic of China 2007; Shen and Liang 2003.

Andes, of which 70 percent are located in Peru and 20 percent in Bolivia. The remaining mass is accounted for by Colombia and Ecuador. Since the early 1970s, it is estimated that, the surface area of glaciers in Peru has declined between 20 and 30 percent, with the Quelcayya ice cap in the vast Cordillera Blanca range losing almost a third of its area. Some of the smaller glaciers in Bolivia have already disappeared (figure 2.7). Research by the World Bank predicts that many of the lower glaciers in the Andes will be a matter for the history books within a decade.[79]

One immediate danger is that melting ice will lead to the formation of larger glacial lakes, leading to increased risk of flooding, avalanches, mudslides and the bursting of dams. The warning signs are already evident: for example, the surface area of Lake Safuna Alta, in the Cordillera Blanca in Peru, has increased by a factor of five since 1975.[80] Many basins fed by glaciers have experienced an increase in runoff in recent years. However, models predict a rapid fall-off in flows after 2050, especially in the dry season.

This is a particular concern for Peru. Populations living in arid coastal areas, including the capital Lima, depend critically on water supplies from melting glaciers in the Andes. In a country that is already struggling to provide basic water services to urban populations, glacial

Figure 2.7 **Latin America's retreating glaciers**



Source: Painter 2007, based on data from the Andean Community.

melting poses a real and imminent threat to human development (box 2.9).

Rising seas and exposure to extreme weather risks

The IPCC projection: It is likely that tropical cyclones—typhoons and hurricanes—will become more intense as oceans warm, with higher peak speeds and heavier precipitation. All typhoons and hurricanes are driven by energy released from the sea—and energy levels will rise. One study has found a doubling of power dissipation in tropical cyclones over the past three decades.[81] Sea levels will continue to rise, though there is uncertainty about by how much. Oceans have absorbed over 80 percent of the increased heat generated by global warming, locking the world into continued thermal expansion.[82] Drought and floods will become more frequent and widespread across much of the world.

The human development projection: Emerging risk scenarios threaten many dimensions of human development. Extreme and unpredictable weather events are already a major source of poverty. They bring near-term human insecurity and destroy long-term efforts aimed at raising productivity, improving health and developing education, perpetuating the low human development traps described earlier in this chapter. Many countries have large and highly vulnerable populations that will face a steep increase in climate-related risks, with people living in coastal areas, river deltas, urban slums and drought-prone regions facing immediate threats.

Climate change is only one of the forces that will influence the profile of risk exposure in the decades ahead. Other global processes—ecological stress, urbanization and population growth among them—will also be important. However, climate change will reconfigure patterns of risk and vulnerability across many regions. The combination of increasing climate hazards and declining resilience is likely to prove a lethal mix for human development.

Any increase to climate-related risk exposure has to be assessed against the backdrop of current exposure. That backdrop includes the following numbers of people facing climate-related hazards:[83]

- 344 million exposed to tropical cyclones;
- 521 million exposed to floods;
- 130 million exposed to droughts;
- 2.3 million exposed to landslides.

As these figures indicate, even small increases to risk over time will affect very large numbers of people. Like climate change itself, the potential linkages between changing weather patterns and evolving trends in risk

Box 2.9 Melting glaciers and retreating prospects for human development

For centuries, the runoff from glaciers in the Andean range has watered agricultural lands and provided human settlements with a predictable flow of water. Today, the glaciers are among the early casualties of climate change. They are melting fast—and their impending disappearance has potentially negative implications for human development in the Andean region.

Peru and Bolivia are the location for the world's largest expanse of tropical glaciers—around 70 percent of the total for Latin America is in Peru and 20 percent in Bolivia. These countries are also home to some of the largest concentrations of poverty and social and economic inequalities in Latin America—the world's most unequal region. Glacial melt threatens not just to diminish water availability, but to exacerbate these inequalities.

Geography is part of the explanation for the risks now facing countries like Peru. Eastern Peru has 98 percent of the country's water resources, but two in every three Peruvians live on the western desert coast—one of the world's most arid regions. Urban water supplies and economic activity are sustained by some 50 rivers flowing from the Andes, with around 80 percent of the fresh water resources originating from snow or glacial melt. Glacier-fed surface waters constitute the source of water, not only for many rural areas but also for major cities and hydroelectric power generation.

Peru has registered some of the most rapid rates of glacial retreat in the world. Between 20 and 30 percent of the glacial surface area has been lost in the last three decades. That area is equivalent to the total glacial surface in Ecuador.

The capital city Lima, with a population of nearly 8 million, is on the coast. Lima gets its water from the Rio Rimac and other rivers in the Cordillera Central, all of which depend to varying degrees on glacial melt. There is already a large gap between supply and demand for water. Overall population is growing at 100,000 a year, driving up demand for water. Rationing is already common in the summer. With limited reservoir storage and exposure to drought increasing, the city would face more rationing in the short term.

Rapid glacial recession in the vast Cordillera Blanca, in the northern Andes, would call into question the future of agriculture, mining, power generation and water supplies across large areas. One of the rivers nourished by the Cordillera Blanca is the Rio Santa. The river sustains a wide array of livelihoods and economic activity. At altitudes of between 2,000 and 4,000 metres, the river delivers the water that irrigates mostly small-scale agriculture. In the lower valleys it irrigates large-scale commercial agriculture, including two large irrigation projects for export crops. Its flow generates hydroelectric power and delivers drinking water to two major urban areas on the Pacific coast—Chimbote and Trujillo—with a combined population of more than one million people.

The problem is that up to 40 percent of the dry season discharge from the Rio Santa originates in melting ice that is not being replenished through annual precipitation. Major economic losses and damage to livelihoods could result. The Chavimochic irrigation scheme on the Rio Santa has contributed to a remarkable national boom in non-traditional agriculture. Total exports from the sector increased from US$302 million in 1998 to US$1 billion in 2005. The boom has been sustained by water-intensive products such as artichokes, asparagus, tomatoes and other vegetables. Glacial melting threatens to erode the viability of investments in irrigation, undermining employment and economic growth in the process.

Monitoring the retreat of tropical glaciers in the Peruvian Andes is relatively straightforward. Developing a response is more challenging. Compensating for the loss of glacial flows in the medium term will require billions of dollars of investment in the construction of tunnels beneath the Andes. Compensating for power losses will require investments in thermal power generation estimated by the World Bank at US$1.5 billion. The price tag points to tough questions about cost sharing at both the domestic and international levels. People in Peru are not responsible for glacial melting: they account for 0.1 percent of the world's carbon emissions. Yet they face the prospect of paying a high financial and human price for the far higher carbon emissions of other countries.

Source: Carvajal 2007; CONAM 2004; Coudrain, Francou and Kundzewicz 2005; Painter 2007.

and vulnerability are complex. They are also non-linear. There is no ready-made calculus for assessing the human development impact of a 2-metre sea-level rise coupled with an increase in tropical storm intensity. But it is possible to identify some of the linkages and transmission mechanisms.

Drought

Increased exposure to drought is of particular concern in sub-Saharan Africa, though other regions, including South Asia and Latin America, could also be affected. Agricultural production is likely to suffer in these regions, especially those dominated by rainfed production. In sub-Saharan Africa, the areas suitable for agriculture, the length of growing seasons and the yield potential of food staples are all projected to decline (see section on Agricultural production and food security above). By 2020, between 75 million and 250 million more people in sub-Saharan Africa could have their livelihoods and human development prospects compromised by a combination of drought, rising temperature and increased water stress.[84]

Floods and tropical storms

There are large margins of uncertainty in projections for populations exposed to risk from flooding.[85] Accelerated disintegration of the West Antarctic ice sheet could multiply sea-level rises by a factor of five over and above the ceiling predicted by the IPCC. However, even more benign scenarios are a source of concern.

One model using an IPCC scenario for high population growth estimates the number of additional people experiencing coastal flooding at 134–332 million for a 3–4°C rise in temperature.[86] Factoring in tropical storm activity could increase the numbers affected to 371 million by the end of the 21st Century.[87] Among the consequences of a 1-metre rise in sea levels:

- In Lower Egypt, possible displacement of 6 million people and flooding of 4,500km² of farmland. This is a region marked by high levels of deprivation in many rural areas, with 17 percent of the population—some 4 million people—living below the poverty line.[88]
- The displacement of up to 22 million people in Viet Nam, with losses of up to 10 percent of GDP. Flooding and more intensive storms could slow human development progress in major population areas, including the Mekong Delta (box 2.10).
- In Bangladesh, one metre rise in sea level would innundate 18 percent of land area, directly threatening 11 percent of the population. The impact on river levels from sea rises could affect over 70 million people.[89]

While most of the people affected by rising sea levels live in a small number of countries with large populations, the impacts will be far more widely distributed (table 2.5). For many low-lying small-island states, rising sea levels and storms point to a highly predictable social, economic and ecological crisis. For the Maldives, where 80 percent of the land area is less than 1 metre above sea level, even the most

Box 2.10 Climate change and human development in the Mekong Delta

Over the past 15 years, Viet Nam has made spectacular progress in human development. Poverty levels have fallen and social indicators have improved, putting the country ahead of schedule on almost all of the MDGs. Climate change poses a real and imminent danger to these achievements—and nowhere more so than in the Mekong Delta.

Viet Nam has a long history of dealing with extreme weather. Located in a typhoon zone, with a long coastline and extensive river deltas, the country is close to the top of the natural disasters league table. On average, there are six to eight typhoons each year. Many leave an extensive trail of destruction, killing and injuring people, damaging homes and fishing boats, and destroying crops. The country's 8,000 kilometres of sea and river dykes, some of which have been developed through communal labour over centuries, testify to the scale of national investment in risk management.

The Mekong Delta is an area of special concern. One of the most densely populated parts of Viet Nam, it is home to 17.2 million people. It is also the 'rice basket' of the country, playing a critical role in national food security. The Mekong Delta produces half of Viet Nam's rice and an even larger share of fisheries and fruit products.

The development of agriculture has played a pivotal role in poverty reduction in the Mekong Delta. Investment in irrigation and support for marketing and extension services has enabled farmers to intensify production, growing two or even three crops a year. Farmers have also constructed dykes and embankments to protect their fields from the flooding that can accompany typhoons and heavy rains.

Climate change poses threats at several levels. Rainfall is predicted to increase and the country will face more intensive tropical storms. Sea levels are expected to rise by 33 cm by 2050 and 1 metre by 2100.

For the low-lying Mekong Delta this is a particularly grim forecast. The sea-level rise projected for 2030 would expose around 45 percent of the Delta's land area to extreme salinization and crop damage through flooding. Crop productivity for rice is forecast to fall by 9 percent. If sea levels rise by 1 metre, much of the Delta would be completely inundated for some periods of the year.

How might these changes impact on human development in the Mekong Delta? While poverty levels have been falling, inequality has been increasing, driven partly by high levels of landlessness. There are still 4 million people living in poverty in the Delta. Many of these people lack basic health protection and school drop-out rates for their children are high. For this group, even a small decline in income or loss of employment opportunities linked to flooding would have adverse consequences for nutrition, health and education. The poor face a double risk. They are far more likely to live in areas vulnerable to flooding—and they are less likely to live in more robust permanent homes.

Source: Chaudhry and Ruysschaert 2007; Nguyen 2007; UNDP and AusAID 2004.

benign climate change scenarios point to deep vulnerabilities.

Small-island developing states are on the front line of climate change. They are already highly vulnerable to climate disasters. Annual damages for the Pacific islands of Fiji, Samoa and Vanuatu are estimated at 2–7 percent of GDP. In Kiribati, one estimate of the combined annual damage bill from climate change and sea-level rises in the absence of adaptation puts the figure at a level equivalent to 17–34 percent of GDP. [90]

Islands in the Caribbean are also at risk. With a 50 centimetre increase in sea levels, over one-third of the Caribbean's beaches would be lost, with damaging implications for the region's tourist industry. An increase of 1 metre would permanently submerge about 11 percent of the land area in the Bahamas. Meanwhile, the intrusion of salt water would compromise freshwater supplies, forcing governments to undertake costly investments in desalination.[91]

More intense tropical storm activity is one of the givens of climate change. Warming seas will fuel more powerful cyclones. At the same time, higher sea temperatures and wider climate change may also alter the course of cyclone tracks and the distribution of storm activity. The first-ever hurricane in the South Atlantic struck Brazil in 2004, and 2005 marked the first hurricane to hit the Iberian peninsula since the 1820s.

Scenarios for tropical storm activity demonstrate the importance of interactions with social factors. In particular, rapid urbanization is placing a growing population in harm's way. Approximately 1 billion people already live in informal urban settlements, and numbers are rising. UN-HABITAT estimates that if current trends continue there will be 1.4 billion people living in slums by 2020 and 2 billion by 2030: one in every three urban dwellers. While more than half the world's slum population today lives in Asia, sub-Saharan Africa has some of the world's fastest growing slums.[92]

Living in makeshift homes often located on hillsides vulnerable to flooding and landslides, slum dwellers are both highly exposed and highly vulnerable to climate change impacts.

Table 2.5 Rising sea levels would have large social and economic impacts

Magnitude of sea level rise (m)	Impact (% of global total)					
	Land area	Population	GDP	Urban area	Agricultural area	Wetland area
1	0.3	1.3	1.3	1.0	0.4	1.9
2	0.5	2.0	2.1	1.6	0.7	3.0
3	0.7	3.0	3.2	2.5	1.1	4.3
4	1.0	4.2	4.7	3.5	1.6	6.0
5	1.2	5.6	6.1	4.7	2.1	7.3

Source: Dasgupta et al. 2007.

These impacts will not be determined purely through physical processes. Public policies can improve resilience in many areas, ranging from flood control to infrastructural protection against landslides and the provision of formal settlement rights to urban slum dwellers. In many cases the absence of formal rights is a deterrent to investment in more robust building materials.

Climate change will create mounting threats. Even robust mitigation will do little to lessen those threats until 2030. Until then, the urban poor will have to adapt to climate change. Supportive public policies could help that adaptation. The starting points: creating more secure tenure rights, investing in slum upgrading and providing clean water and sanitation to the urban poor.

Ecosystems and biodiversity

IPCC projection: There is a high confidence probability that the resilience of many ecosystems will be undermined by climate change, with rising CO_2 levels reducing biodiversity, damaging ecosystems and compromising the services that they provide.

Human development projection: The world is heading towards unprecedented losses of biodiversity and the collapse of ecological systems during the 21st Century. At temperature increases in excess of 2°C, rates of extinction will start to increase. Environmental degradation will gather pace, with coral, wetland and forest systems suffering rapid losses. The processes are already under

Losses of biodiversity are mounting in many regions. Climate change is one of the forces driving these trends. Over time it will become a more powerful force

way. Losses of ecosystems and biodiversity are intrinsically bad for human development. The environment matters in its own right for current and for future generations. However, vital ecosystems that provide wide ranging services will also be lost. The poor, who depend most heavily on these services, will bear the brunt of the cost.

As in other areas, the processes of climate change will interact with wider pressures on ecosystems and biodiversity. Many of the world's great ecosystems are already under threat. Losses of biodiversity are mounting in many regions. Climate change is one of the forces driving these trends. Over time it will become a more powerful force.

The rapidly deteriorating state of the global environment provides the context for assessing the impact of future climate change. In 2005, the *Millennium Ecosystem Assessment* found that 60 percent of all ecosystem services were either degraded or being used unsustainably.[93] The loss of mangrove swamps, coral reef systems, forests and wetlands was highlighted as a major concern, with agriculture, population growth and industrial development acting together to degrade the environmental resource base. Nearly one in four mammal species is in serious decline.[94]

Losses of environmental resources will compromise human resilience in the face of climate change. Wetlands are an example. The world's wetlands provide an astonishing range of ecological services. They harbour biodiversity, provide agricultural, timber and medicinal products, and sustain fish stocks. More than that, they buffer coastal and riverside areas from storms and floods, protecting human settlements from sea surges. During the 20th Century, the world lost half its wetlands through drainage, conversion to agriculture and pollution. Today, the destruction continues apace at a time when climate change threatens to generate more intensive storms and sea surges.[95] In Bangladesh, the steady erosion of the mangrove areas in the Sundabarns and other regions has undermined livelihoods while increasing exposure to rising sea levels.

Climate change is transforming the relationship between people and nature. Many ecosystems and most species are highly susceptible to shifts in climate. Animals and plants are adapted to specific climate zones. Only one species has the ability to adjust the climate through thermostats attached to heating or cooling devices—and that is the species responsible for global warming. Plants and animals have to adapt by moving.

Ecological maps are being redrawn. Over the past three decades, the lines marking regions in which average temperatures prevail—'isotherms'—have been moving towards the North and South Poles at a rate of about 56 kilometres per decade.[96] Species are attempting to follow their climate zones. Changes in flowering seasons, migratory patterns and the distribution of flora and fauna have been detected across the world. Alpine plants are being pushed towards higher altitudes, for example. But when the pace of climate change is too rapid, or when natural barriers such as oceans block migration routes, extinction looms. The species most at risk are those in polar climates, because they have nowhere to go. Climate change is literally pushing them off the planet.

Climate change has already contributed to a loss of species—and global warming in the pipeline will add to that loss. But far greater impacts will take off at 2°C over preindustrial levels. This is the threshold at which predicted extinction rates start to rise. According to the IPCC, 20–30 percent of plant and animal species are likely to be at increased risk of extinction if global average temperature increases exceed 1.5–2.5°C, including polar bears and fish species that feed on coral reefs. Some 277 medium or large mammals in Africa would be at risk in the event of 3°C warming.[97]

The Arctic under threat

The Arctic region provides an antidote to the view that climate change is an uncertain future threat. Here, fragile ecological systems have come into contact with rapid and extreme temperature increases. Over the past 50 years, mean annual surface temperature in areas from

Alaska to Siberia has increased by 3.6°C—more than twice the global average. Snow cover has declined by 10 percent in the past 30 years, and average sea ice cover by 15–20 percent. Permafrost is melting and the tree line is shifting northwards.

Climate change scenarios point in a worrying direction. Mean surface temperatures are projected to increase by another 3°C by 2050, with dramatic reductions in summer sea ice, the encroachment of forests into tundra regions, and extensive loss of ecosystems and wildlife. Entire species are at risk. As the Arctic Climate Impact Assessment puts it: "Marine species dependent on sea ice, including polar bears, ice-living seals, walrus and some marine birds, are very likely to decline, with some facing extinction."[98]

The United States has acknowledged the impact of climate change on the Arctic. In December 2006, the US Department of the Interior proposed, on the basis of "the best scientific evidence", placing the polar bear on the Endangered Species list. That act effectively acknowledges the role played by climate change in increasing its vulnerability—and it requires government agencies to protect the species. More recently, polar bears have been joined on the list by 10 species of penguin which are also under threat. Unfortunately, the "best scientific evidence" points in a worrying direction: within a couple of generations, the only polar bears on the planet could be those on display in the world's zoos. The late summer Arctic sea ice, on which they depend for hunting, has been shrinking at over 7 percent a decade since the late 1970s. Recent scientific studies of adult polar bears in Canada and Alaska have shown weight loss, reduced cub survival, and an increase in the number of bears drowning as they are forced to swim further in search of prey. In western Hudson Bay, populations have fallen by 22 percent.[99]

The United States Department of the Interior's actions establish an important principle of shared responsibility across borders. That principle has wider ramifications. Polar bears cannot be treated in isolation. They are part of a wider social and ecological system. And if the impact of climate change and associated responsibilities of governments are recognized for the Arctic the principle should be more widely applied. People living in drought-prone areas of Africa and flood-prone regions of Asia are also affected. Applying one set of rules for polar bears and another for vulnerable people in approaches to climate change mitigation and adaptation would be inconsistent.

The sheer pace of climate change across the Arctic is creating challenges at many levels. Loss of permafrost could unlock vast amounts of methane—a potent greenhouse gas that could undermine mitigation efforts by acting as a driver for 'positive feedbacks'. The rapid melting of Arctic ice has opened up new areas to exploration for oil and natural gas, giving rise to tensions between states over the interpretation of the 1982 Convention on the Law of the Sea.[100] Within countries, climate change could lead to immense social and economic harm, damaging infrastructure and threatening human settlements.

Scenarios for Russia illustrate the point. With climate change, Russia will experience warming effects that could raise agricultural production, though increased exposure to drought may negate any benefits. One of the more predictable consequences of climate change for Russia is increased thawing of the permafrost which covers approximately 60 percent of the country. Thawing has already led to increases in winter flows of major rivers. Accelerated melting will affect coastal and river bank human settlements, exposing many to flood risks. It will also require heavy investments in infrastructural adaptation, with roads, electrical transmission lines and the Baikal Amur railway potentially affected. Plans are already being drawn up to protect the planned East Siberia–Pacific export oil pipeline through extensive trenching to combat coastal erosion linked to permafrost melting—a further demonstration that ecological change carries real economic costs.[101]

The coral reef—a climate change barometer

Arctic regions provide the world with a highly visible early warning system for climate change.

The "best scientific evidence" points in a worrying direction: within a couple of generations, the only polar bears on the planet could be those on display in the world's zoos

Coral reefs are not just havens of exceptional biodiversity, but also a source of livelihoods, nutrition and economic growth for over 60 countries

Other ecosystems provide an equally sensitive though less immediately visible barometer. Coral reefs are an example. During the 21st Century, warming oceans and rising acidification could destroy much of the world's coral, with devastating social, ecological and economic consequences.

Warming seas have contributed to the destruction of coral reefs on an extensive scale, with half of all systems in decline.[102] Even fairly short periods of abnormally high temperature—as little as 1°C higher than the long term average—can cause corals to expel the algae that supply most of their food, resulting in 'bleaching' and sudden death of the reef.[103]

The world's coral reef systems already bear scars from climate change. Around half these systems have already been affected by bleaching. The 50,000 km^2 of coral reef in Indonesia, 18 percent of the world's total, is deteriorating rapidly. One survey in Bali Barat National Park in 2000 found that the majority of the reef had been degraded, most of it by bleaching.[104] Aerial views of the Great Barrier Reef in Australia also capture the extent of bleaching.

There could be far worse to come. With average temperature increases above 2°C, annual bleaching would be a regular event. The major bleaching events that accompanied the 1998 El Niño, when 16 percent of the world's coral was destroyed in 9 months, would become the rule, rather than the exception. Localized bleaching episodes are becoming more frequent in many regions, providing a worrying pointer for the future. For example, in 2005, the eastern Caribbean suffered one of the worst bleaching episodes on record.[105]

Bleaching is just one of the threats posed by climate change. Many marine organisms, including coral, make their shells and skeletons out of calcium carbonate. The upper ocean is super-saturated with these minerals. However, the increases in ocean acidity caused by the 10 billion tonnes of CO_2 being absorbed by the oceans each year attacks carbonate, removing one of the essential building blocks needed by coral.[106]

Marine scientists have pointed to a worrying parallel. Ocean systems respond slowly and over very long time horizons to changes in the atmospheric environment. Business-as-usual climate change in the 21st Century could make the oceans more acidic over the next few centuries than they have been at any time for 300 million years, with one exception: a single catastrophic episode that occurred 55 million years ago. That episode was the result of the rapid ocean acidification caused by the release of 4,500 gigatonnes of carbon.[107] It took over 100,000 years for the oceans to return to their previous acidity levels. Meanwhile, geological records show a mass extinction of sea creatures. As one of the world's leading oceanographers puts it: "Nearly every marine organism that made a shell or a skeleton out of calcium carbonate disappeared from the geologic record ... if CO_2 emissions are unabated, we may make the oceans more corrosive to carbonate minerals than at any time since the extinction of the dinosaurs. I personally believe that this will cause the extinction of corals."[108]

The collapse of coral systems would represent a catastrophic event for human development in many countries. Coral reefs are not just havens of exceptional biodiversity, but also a source of livelihoods, nutrition and economic growth for over 60 countries. Most of the 30 million small-scale fishers in the developing world are dependent in some form on coral reefs for maintaining feeding and breeding grounds. More than half of the protein and essential nutrients in the diets of 400 million poor people living in tropical coastal areas is supplied by fish.

Coral reefs are a vital part of the marine ecosystems that sustain fish stocks, though warming oceans pose wider threats. In Namibia, anomalously warm water currents in 1995—the Benguela Niño current—resulted in fish stocks moving 4–5° of latitude south—an outcome that destroyed a small-scale fisheries industry for pilchards.[109]

Beyond their value in the lives and nutrition of the poor, corals have a wider economic value. They generate income, exports and, in regions such as the Indian Ocean and the Caribbean, support tourism. Recognition of the important role of coral in economic, ecological and social life has prompted many governments and aid

donors to invest in rehabilitation. The problem is that climate change is a powerful force pulling in the other direction.

Human health and extreme weather events

IPCC projection: Climate change will affect human health through complex systems involving changes in temperature, exposure to extreme events, access to nutrition, air quality and other vectors. Currently small health effects can be expected with very high confidence to progressively increase in all countries and regions, with the most adverse effects in low-income countries.

Human development projection: Climate will interact with human health in diverse ways. Those least equipped to respond to changing health threats—predominantly poor people in poor countries—will bear the brunt of health setbacks. Ill-health is one of the most powerful forces holding back the human development potential of poor households. Climate change will intensify the problem.

Climate change is likely to have major implications for human health in the 21st Century. Large areas of uncertainty surround assessments, reflecting the complex interaction between disease, environment and people. However, in health, as in other areas, recognition of uncertainty is not a case for inaction. The World Health Organization (WHO) predicts that the overall impact will be negative.[110]

Public health outcomes linked to climate change will be shaped by many factors. Pre-existing epidemiology and local processes will be important. So, too, will pre-existing levels of human development and the capacities of public health systems. Many of the emerging risks for public health will be concentrated in developing countries where poor health is already a major source of human suffering and poverty—and where public health systems lack the resources (human and financial) to manage new threats. An obvious danger is that climate change under these conditions will exacerbate already extreme global inequalities in public health.

Malaria gives rise to some of the greatest causes for concern. This is a disease that currently claims around 1 million lives annually, over 90 percent of them in Africa. Some 800,000 children under the age of 5 in sub-Saharan Africa die as a result of malaria each year, making it the third largest killer of children worldwide.[111] Beyond these headline figures, malaria causes immense suffering, robs people of opportunities in education, employment and production, and forces people to spend their limited resources on palliative treatment. Rainfall, temperature and humidity are three variables that most influence transmission of malaria—and climate change will affect all three.

Increased rain, even in short downpours, warmer temperatures and humidity create a 'perfect storm' for the spread of the *Plasmodium* parasite that causes malaria. Rising temperatures can extend the range and elevation of mosquito populations, as well as halving incubation periods. For sub-Saharan Africa in particular, any extension of the malaria range would pose grave risks to public health. Some four in five people in the region already live in malarial areas. Future projections are uncertain, though there are concerns that the malarial range could expand in upland areas. More disconcerting still, the seasonal transmission period may also increase, effectively increasing average per capita exposure to malarial infection by 16–28 percent.[112] Worldwide it is estimated that an additional 220–400 million people could be exposed to malaria.[113]

Changing weather patterns are already producing new disease profiles in many regions. In eastern Africa, flooding in 2007 created new breeding sites for disease vectors such as mosquitoes, triggering epidemics of Rift Valley Fever and increasing levels of malaria. In Ethiopia, an epidemic of cholera following the extreme floods in 2006 led to widespread loss of life and illness. Unusually dry and warm conditions in eastern Africa have been linked to the spread of *chikungunya* fever, a viral disease that has proliferated across the region.[114]

Climate change could also increase the population exposed to dengue fever. This is a highly climate-sensitive disease that is currently

Changing weather patterns are already producing new disease profiles in many regions

Urgent action is needed to conduct assessments of the risks posed by climate change to public health in the developing world, followed by a mobilization of resources to create an enabling environment for risk management

largely confined to urban areas. Latitudinal expansion linked to climate change could increase the population at risk from 1.5 billion people to 3.5 billion by 2080.[115] Dengue fever is already in evidence at higher elevations in previously dengue-free areas of Latin America. In Indonesia, warmer temperatures have led to the mutation of the dengue virus, leading to an increase in fatalities in the rainy season. While there is no proven evidence that climate change is implicated, in the late 1990s El Niño and La Niña events in the country were associated with severe outbreaks of both dengue and malaria, with malaria spreading to high elevations in the highlands of Irian Jaya.[116]

Extreme climate events provide another set of threats. Floods, droughts and storms bring in their wake increased health risks, such as cholera and diarrhoea among children. There is already evidence in developing countries of the impacts of rising temperatures. During 2005, Bangladesh, India and Pakistan faced temperatures 5–6°C above the regional average. There were 400 reported deaths in India alone, though unreported deaths would multiply this figure many times over.[117] Public health in developed countries has not been immune. The heat-wave that hit Europe in 2003 claimed between 22,000 and 35,000 lives, most of them elderly. In Paris, the worst affected city, 81 percent of the victims were aged over 75 years.[118] More events of this nature are likely. For example, the incidence of heat waves in most United States' cities is expected to approximately double by 2050.[119]

Public health authorities in rich nations are being forced to confront the challenges posed by climate change. The city of New York provides an example of a wider process. Climate impact assessments have pointed to higher summer-season temperatures, with increasing frequency and duration of heat waves. The prognosis: a projected increase in summer-season heat stress morbidity, particularly among the elderly poor. Summer heat-related mortality could increase 55 percent by the 2020s, more than double by the 2050s and more than triple by the 2080s.[120] Climate change could also contribute indirectly to at least three classes of wider health problems: incidence of certain vector-borne diseases such as West Nile Virus, Lyme disease and malaria may rise; water-borne disease organisms may become more prevalent; and photochemical air pollution may increase.[121] Strategies are being developed to address the risks.

Governments in the developed world have to respond to the public health threats posed by climate change. Many authorities—as in New York—acknowledge the special problems faced by poor and vulnerable populations. Yet it would be wrong for countries with first class health systems and the financial resources needed to counteract climate change threats at home, to turn a blind eye to the risks and vulnerabilities faced by the poor in the developing world. Urgent action is needed to conduct assessments of the risks posed by climate change to public health in the developing world, followed by a mobilization of resources to create an enabling environment for risk management. The starting point for action is the recognition that rich countries themselves carry much of the historic responsibility for the threats now facing the developing world.

Conclusion

"We are made wise not by the recollection of our past" wrote George Bernard Shaw, "but by the responsibility for our future." Viewed from the perspective of human development, climate change brings the past and the future together.

In this chapter we have looked at the 'early harvest' climate change catastrophe. That harvest, which has already begun, will initially slow progress in human development. As climate change develops, large-scale reversals will become

more likely. Evidence from the past provides us with insights into the processes that will drive these reversals, but the future under climate change will not look like the past. Setbacks for human development will be non-linear, with powerful mutually reinforcing feedback effects. Losses in agricultural productivity will reduce income, diminishing access to health and education. In turn, reduced opportunities in health and education will restrict market opportunities and reinforce poverty. At a more fundamental level, climate change will erode the ability of the world's most vulnerable people to shape decisions and processes that impact on their lives.

Catastrophic human development setbacks are avoidable. There are two requirements for changing the 21st Century scenario to a more favourable direction. The first is climate change mitigation. Without early and deep cuts in emissions of CO_2, dangerous climate change will happen—and it will destroy human potential on a vast scale. The consequences will be reflected in surging inequalities within and across countries and rising poverty. Rich countries may escape the immediate effects. They will not escape the consequences of the anger, resentment and transformation of human settlement patterns that will accompany dangerous climate change in poor countries.

The second requirement for averting the threats set out in this chapter is adaptation. No amount of mitigation will protect vulnerable people in developing countries from the incremental climate change risks that they face today, or from the global warming to which the world is already committed. Increased risk exposure is inevitable—human development reversals are not. Adaptation is ultimately about building the resilience of the world's poor to a problem largely created by the world's richest nations.

Catastrophic human development setbacks are avoidable