4 Implications of Climate Change for Development

Key Messages

Climate change poses a real threat to the developing world. Unchecked it will become a major obstacle to continued poverty reduction.

Developing countries are especially vulnerable to climate change because of their geographic exposure, low incomes, and greater reliance on climate sensitive sectors such as agriculture. Ethiopia, for example, already has far greater hydrological variability than North America but less than 1% of the artificial water storage capacity per capita. **Together these mean that impacts are proportionally greater and the ability to adapt smaller.**

Many developing countries are already struggling to cope with their current climate. For low-income countries, major natural disasters today can cost an average of 5% of GDP.

Health and agricultural incomes will be under particular threat from climate change. For example:

- Falling farm incomes will increase poverty and reduce the ability of households to invest in a better future and force them to use up meagre savings just to survive.
- Millions of people will potentially be at risk of climate-driven heat stress, flooding, malnutrition, water related disease and vector borne diseases. For example, dengue transmission in South America may increase by 2 to 5 fold by the 2050s.
- The cost of climate change in India and South East Asia could be as high as a 9-13% loss in GDP by 2100 compared with what could have been achieved in a world without climate change. Up to an additional 145-220 million people could be living on less than $2 a day and there could be an additional 165,000 to 250,000 child deaths per year in South Asia and sub-Saharan Africa by 2100 (due to income losses alone).

Severe deterioration in the local climate could lead, in some parts of the developing world, to mass migration and conflict, especially as another 2-3 billion people are added to the developing world's population in the next few decades:

- Rising sea levels, advancing desertification and other climate-driven changes could drive millions of people to migrate: more than a fifth of Bangladesh could be under water with a 1m rise in sea levels – a possibility by the end of the century.
- Drought and other climate-related shocks risk sparking conflict and violence, with West Africa and the Nile Basin particularly vulnerable given their high water interdependence.

These risks place an even greater premium on fostering growth and development to reduce the vulnerability of developing countries to climate change.

However, little can now be done to change the likely adverse effects that some developing countries will face in the next few decades, and so some adaptation will be essential. Strong and early mitigation is the only way to avoid some of the more severe impacts that could occur in the second half of this century.

4.1 Introduction

While all regions will eventually feel the effects of climate change, it will have a disproportionately harmful effect on developing countries – and in particular poor communities who are already living at or close to the margins of survival. Changes in the climate will amplify the existing challenges posed by tropical geography, a heavy dependence on agriculture, rapid population growth, poverty, and a limited capacity to cope with an uncertain climate. The world is already likely to fall short of the Millennium Development Goals for 2015

in many regions of the world (see Box 4.1 for the Goals). Climate change threatens the long-term sustainability of development progress.[1]

Box 4.1 Millennium Development Goals

In September 2000, 189 countries signed the United Nations Millennium Declaration. In so doing, they agreed on the fundamental dimensions of development, translated into an international blueprint for poverty reduction. This is encapsulated by the Millennium Development Goals that are focused on a target date of 2015:

- Halve extreme poverty and hunger
- Achieve universal primary education
- Empower women and promote equality between women and men
- Reduce under five mortality by two thirds
- Reduce maternal mortality by three-quarters
- Reverse the spread of diseases, especially HIV/AIDS and malaria
- Ensure environmental sustainability
- Create a global partnership for development, with targets for aid, trade and debt relief

But it is important to recognise that the scale of future climate impacts will vary between regions, countries and people. The last 30 years or so has already seen strong advances in many developing countries on income, health and education. Those developing countries that continue to experience rapid growth will be much better placed to deal with the consequences of climate change. Other areas, predominantly low-income countries, where growth is stagnating may find their vulnerability increases.

The challenge now is to limit the damage, both by mitigation and adaptation. It is vital therefore to understand just how, and how much, climate change is likely to slow development progress. The chapter begins by examining the processes by which climate change impacts will be felt in developing counties. Section 4.2 considers what it is about the starting position of these countries that makes them vulnerable to the physical changes set out in Chapter 3. Understanding why developing countries are especially vulnerable is critical to understanding how best to improve their ability to deal with climate change (discussed in Chapter 20). Sections 4.3 and 4.4 move on to consider the consequences of a changing climate on health, income and growth. The first part of the analysis draws on evidence from past and current exposure to climate variability to show how vulnerable groups are affected by a hostile climate. The second summarises key regional impacts. Section 4.5 explores the potential effects on future growth and income levels, which in turn affect the numbers of people living below poverty thresholds as well as the child mortality rate. The chapter concludes with Section 4.6 reviewing the possible consequences for migration, displacement and risk of conflict resulting from the socio-economic and environmental pressures of climate change.

4.2 The vulnerability of developing countries to a changing climate

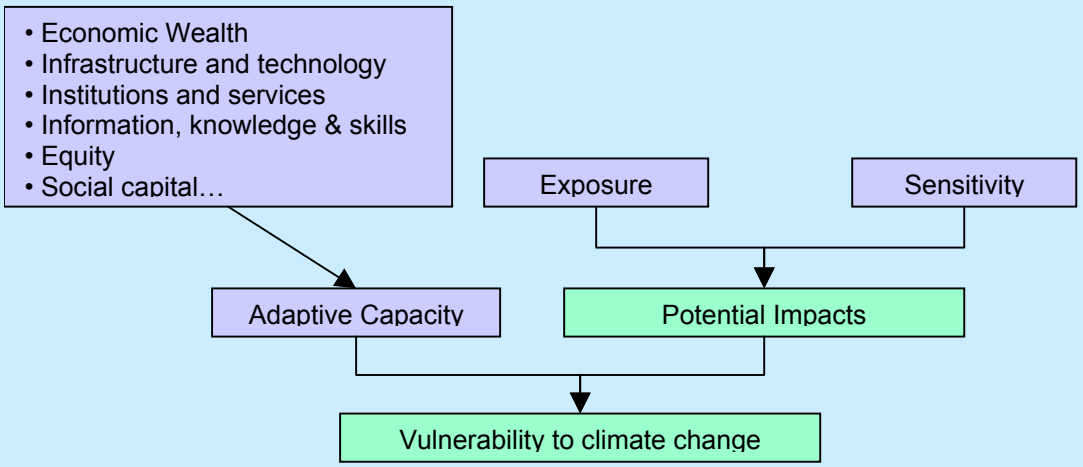
Developing countries are especially vulnerable to the physical impacts of climate change because of their exposure to an already fragile environment, an economic structure that is highly sensitive to an adverse and changing climate, and low incomes that constrain their ability to adapt.

The effects of climate change on economies and societies will vary greatly over the world. The circumstances of each country - its initial climate, socio-economic conditions, and growth prospects – will shape the scale of the social, economic and environmental effects of climate change. Vulnerability to climate change can be classified as: *exposure* to changes in the climate, *sensitivity* – the degree to which a system is affected by or responsive to climate

[1] The physical effects of climate change are predicted to become progressively more significant by the 2050s with a 2 to 3°C warming, as explained in Chapter 3.

stimuli,[2] and *adaptive capacity* - the ability to prepare for, respond to and tackle the effects of climate change. This is illustrated in Figure 4.1. Developing countries score poorly on all three criteria. This section provides a brief overview of some of the key vulnerabilities facing many developing countries. Unless these vulnerabilities are overcome they are likely to increase the risk and scale of damaging impacts posed by climate change.

Figure 4.1 Vulnerability to climate change: the IPCC Third Assessment Report



Source: redrawn from Ionescu et al (2005)

Exposure: The geography of many developing countries leaves them especially vulnerable to climate change.

Geographical exposure plays an important role in determining a country's growth and development prospects. Many developing countries are located in tropical areas. As a result, they already endure climate extremes (such as those that accompany the monsoon and El Niño and La Niña cycles), intra and interannual variability in rainfall,[3] and very high temperatures. India, for example, experienced peak temperatures of between 45°C and 49°C during the pre-monsoon months of 2003.[4] Geographical conditions have been identified as important contributors to lower levels of growth in developing countries. If rainfall - that arrives only in a single season in many tropical areas - fails for example, a country will be left dry for over a year with powerful implications for their agricultural sector. This occurred in India in 2002 when the monsoon rains failed, resulting in a seasonal rainfall deficit of 19% and causing large losses of agricultural production and a drop of over 3% in India's GDP.[5] Recent analysis has led Nordhaus to conclude that "tropical geography has a substantial negative impact on output density and output per capita compared to temperate regions".[6] Sachs, similarly, argues that poor soils, the presence of pests and parasites, higher crop respiration rates due to warmer temperatures, and difficulty in water availability and control explain much of the tropical disadvantage in agriculture.[7] Climate change is predicted to make these conditions even more challenging, with the range of possible physical impacts set out in Chapter 3. Even slight variations in the climate can have very large costs in developing countries as many places are close to the upper temperature tolerance of activities such as crop production. Put anther way, climate change will have a disproportionately damaging

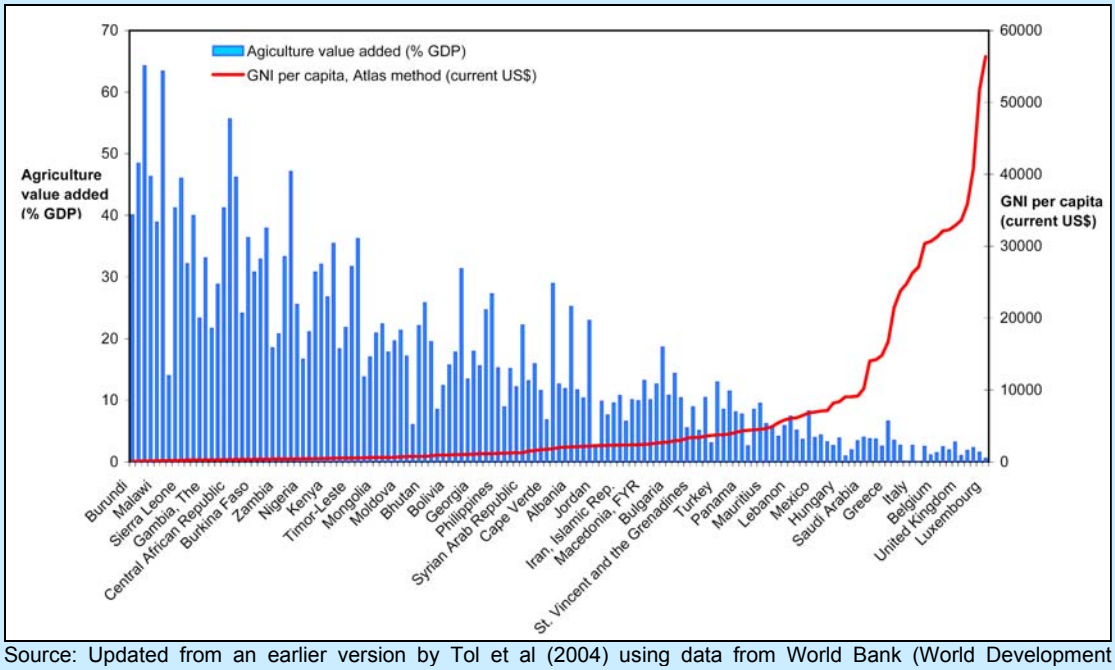
[2] IPCC (2001). The classification of *sensitivity* is similar to *susceptibility* to climate change, the degree to which a system is open, liable, or sensitive to climate stimuli.
[3] Intra-annual variability refers to rainfall concentrated in a single season, whilst interannual variability refers to large differences in the annual total of rainfall. The latter may be driven by phenomena such as the El Nino/Southern Oscillation (ENSO) or longer-term climate shifts such as those that caused the ongoing drought in the African Sahel. Brown and Lall (2006)
[4] De et al (2005)
[5] Challinor et al (2006). The scale of losses in the agricultural sector is indicated by the fact that this sector contributed just over one fifth of GDP at the time.
[6] Nordhaus (2006). Approximately 20% of the difference in per capita output between tropical Africa and two industrial regions is attributed to geography according to Nordhaus' model and analysis.
[7] Sachs (2001a)

impact on developing countries due, in part at least, to their location in low latitudes, the amount and variability of rainfall they receive, and the fact that they are "already too hot".[8]

Sensitivity: Developing economies are very sensitive to the direct impacts of climate change given their heavy dependence on agriculture and ecosystems, rapid population growth and concentration of millions of people in slum and squatter settlements, and low health levels.

Dependence on agriculture: Agriculture and related activities are crucial to many developing countries, in particular for low income or semi-subsistence economies. The rural sector contributes 21% of GDP in India, for example, rising to 39% in a country like Malawi,[9] whilst 61% and 64% of people in South Asia and sub-Saharan Africa are employed in the rural sector.[10] This concentration of economic activities in the rural sector – and in some cases around just a few commodities - is associated with low levels of income, as illustrated in Figure 4.2.[11] The concentration of activities in one sector also limits flexibility to switch to less climate-sensitive activities such as manufacturing and services. The agricultural sector is one of the most at risk to the damaging impacts of climate change – and indeed current extreme climate variability - in developing countries, as discussed in Chapter 3.

Figure 4.2 The share of agriculture in GDP and per capita income in 2004



Source: Updated from an earlier version by Tol et al (2004) using data from World Bank (World Development Indicators for 2004) for all countries for which such data are available. Countries are ranked by per capita income.

Dependence on vulnerable ecosystems: All humans depend on the services provided by natural systems. However, environmental assets and the services they provide are especially important for poor people, ranging from the provision of subsistence products and market income, to food security and health services.[12] Poor people are consequently highly sensitive to the degradation and destruction of these natural assets and systems by climate change. For example, dieback of large areas of forest – some climate models show strong drying over the Amazon if global temperature increases by more than 2°C, for example – would affect

[8] Mendelsohn et al (2006)
[9] World Bank (2006a) using 2004 data
[10] ILO (2005). The employment figures are given as a share of total employment, 2005.
[11] For example, the Central African Republic derives more than 50% of its export earnings from cotton alone (1997/99). Commission for Africa (2005)
[12] Natural medicines, for example, are often the only source of medicine for poor people and can help reduce national costs of supplying medical provisions in developing countries. The ratio of traditional healers to western-trained doctors is approximately 150:1 in some African countries for example. UNEP-WCMC (2006)

many of the one billion or more people who depend to varying degrees on forests for their livelihoods (Table 4.1).[13]

Table 4.1 Direct roles of forests in household livelihood strategies

Poverty aspects	Function	Description
Safety net	Insurance	Food and cash income in periods of unexpected food and income shortfall
Support current consumption	Gap-filling	Regular (seasonal, for example) shortfall of food and income
	Regular subsistence uses	Fuelwood, wild meat, medicinal plants, and so on
	Low-return cash activities	A wide range of extractive or "soft management" activities, normally in economies with low market integration
Poverty reduction	Diversified forest strategies	Forest activities that are maintained in economies with high market integration
	Specialised forest strategies	Forest activities that form the majority of the cash income in local economies with high market integration
	Payment for environmental services	Direct transfers to local communities from off-site beneficiaries

Source: Classification based on Arnold (2001), Kaimowitz (2002), Angelsen and Wunder (2003), and Belcher, Ruiz-perez, and Achdiawan (2003)

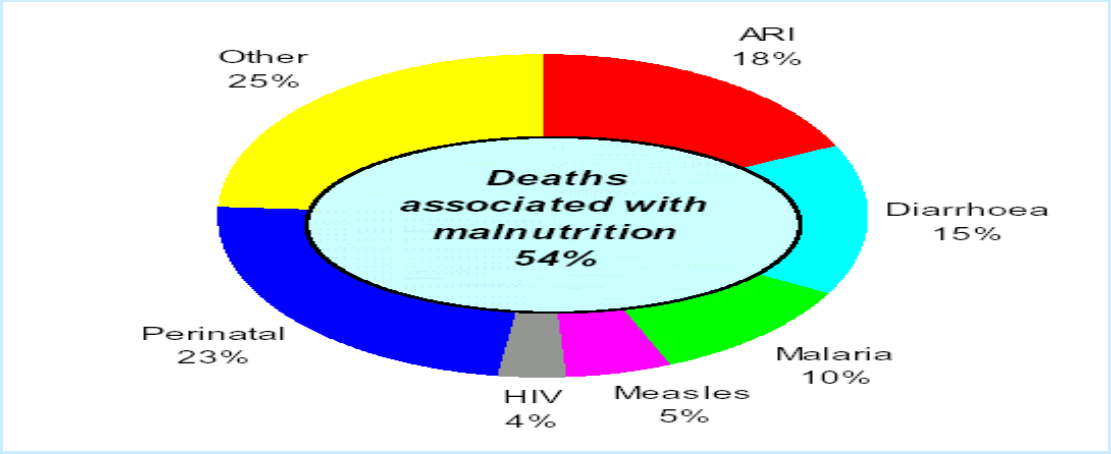
Population growth and rapid urbanisation: Over the next few decades, another 2-3 billion people will be added to the world's population, virtually all of them in developing countries.[14] This will add to the existing strain on natural resources - and the social fabric - in many poor countries, and expose a greater number of people to the effects of climate change. Greater effort is required to encourage lower rates of population growth. Development on the MDG dimensions (in particular income, the education of women, and reproductive health) is the most powerful and sustainable way to approach population growth.[15]

Developing countries are also undergoing rapid urbanisation, and the trend is set to continue as populations grow. The number of people living in cities in developing countries is predicted to rise from 43% in 2005 to 56% by 2030.[16] In Africa, for example, the 500km coast between Accra and the Niger delta will likely become a continuous urban megalopolis with more than 50 million people by 2020.[17] It does not follow from this that policies to slow urbanisation are desirable. Urbanisation is closely linked to economic growth and it can provide opportunities for reducing poverty and decreasing vulnerability to climate change.[18] Nonetheless, many of those migrating to cities live in poor conditions – often on marginal land – and are particularly vulnerable because of their limited access clean water, sanitation, and location in flood-prone areas.[19] In Latin America, for example, where urbanisation has gone far further than in Africa or Asia, more and more people are likely be forced to locate in cheaper, hazard prone areas such as floodplains or steep slopes.

[13] Vedeld et al (2004). This effect on the Amazon has been found with the Hadley Centre model, as reported in Cox *et al.* (2000), and several other climate models (Scholze *et al.* 2006) as discussed in Chapter 3.
[14] World Bank (2003b)
[15] Stern et al (2005)
[16] World Population Prospects (2004); and World Urbanization Prospects (2005).
[17] Hewawasam (2002)
[18] For example, proximity and economies of scale enable cost-effective and efficient targeting and provision of basic infrastructure and services.
[19] Approximately 72% of Africa's urban inhabitants now live in slums and squatter settlements for example (Commission for Africa, 2005)

***Food insecurity, malnutrition and health**:* Approximately 40% of the population of sub-Saharan Africa is undernourished, largely because of the poor diet and severe and repeated infections that afflict poor people.[20] Even if the Millennium Development Goals are met, more than 400 million people could be suffering from chronic hunger in 2015.[21] Malnutrition is a health outcome in itself, but it also lowers natural resistance to infectious diseases by weakening the immune system. This is a challenge today - malnutrition was associated with 54% of child deaths in developing countries in 2001 (10.8 million children), as illustrated in Figure 4.3. Climate change will potentially exacerbate this vulnerability as a greater number of malaria carrying mosquitoes move into previously uninfected areas. This is likely to generate higher morbidity and mortality rates among people suffering from malnutrition than among food-secure people.

Figure 4.3 Proportional mortality in children younger than five years old in developing countries



Source: WHO (2005) Note: Acute Respiratory Infection (ARI)

Adaptive capacity: People will adapt to changes in the climate as far as their resources and knowledge allow. But developing countries lack the infrastructure (most notably in the area of water supply and management), financial means, and access to public services that would otherwise help them adapt.

Poor water-related infrastructure and management: Developing countries are highly dependent on water – the most climate-sensitive economic resource - for their growth and development. Water is a key input to agriculture, industry, energy and transport and is essential for domestic purposes. Irrigation and effective water management will be very important in helping to reduce and manage the effects of climate change on agriculture.[22] But many developing countries have low investment in irrigation systems, dams, and ground water. For example, Ethiopia has less than 1% of the artificial water storage capacity per capita of North America, despite having to manage far greater hydrological variability.[23] Many developing countries do not have enough water storage to manage annual water demand based on the current average seasonal rainfall cycle, as illustrated in Table 4.2. This will become an even greater bind with a future, less predictable cycle.

[20] WHO (2005). Poverty impacts a person's standard of living, the environmental conditions in which they live, and their ability to meet basic needs such as food, housing and health care that in turn affects their level of nutrition.
[21] One of the MDGs is to halve, between 1990 and 2015, the proportion of people who suffer from hunger. In 2002 there were 815 million hungry people in the developing world, 9 million less than in 1990. (UN, 2005)
[22] Irrigation plays an important role in improving returns from land, with studies identifying an increase in cropping intensity of 30% with the use of irrigation (Commission for Africa, 2005). Similarly, effective water management enables water to be stored for multiple uses, increases the reliability of water services, reduces peak flows and increases off-peak flows, and reduces the risk of water-related shocks and damage (World Bank, 2006b).
[23] World Bank (2006c)

Table 4.2 Investment in water storage in developing countries

The seasonal storage index (SSI) indicates the volume of storage needed to satisfy annual water demand based on the average seasonal rainfall cycle (calculated as the volume needed to transfer water from wet months to dry months). The countries listed below need water during dry seasons and have water available to be captured during wet seasons. The 'Hard Water' column represents water storage requirements. Surface water reservoir development or groundwater development could provide additional storage. Some developing countries will also require 'soft water' (with water needs in excess of the volume that can be captured from internal renewable water resources) through increasing the efficiency of water use. However, the average GDP of countries with soft water needs is $8,477 compared to an average GDP of $601 of countries with hard water requirements. South Asia faces problems of seasonal and inter-annual deficits, requiring both seasonal and inter-annual storage, and 'soft' water.[24]

	Seasonal Storage Index (km3)	SSI as % of Annual Volume	% Hard Water (of total)	Current Storage (% of SSI)	GDP ($, 2003)
India	356.6	21%	17%	76%	555
Bangladesh	62.28	41%	40%	33%	385
Ethiopia	40.99	10%	100%	8%	91
Nepal	29.86	47%	100%	0%	233
Vietnam	27.64	10%	100%	3%	471
North Korea	23.32	45%	100%	0%	494
Senegal	22.3	40%	100%	7%	641
Malawi	18.98	34%	100%	0%	158
Algeria	6.6	6%	100%	91%	2,049
Tanzania	5.5	1%	33%	76%	271
El Salvador	5.45	37%	100%	59%	2,302
Haiti	3.73	25%	79%	0%	300
Guinea	3.71	2%	100%	51%	424
Eritrea	2.75	11%	15%	3%	305
Burundi	2.64	19%	27%	0%	86
Albania	2.64	23%	100%	21%	1,915
Guinea-Bissau	2.48	11%	100%	0%	208
Sierra Leone	2.21	3%	100%	0%	197
The Gambia	2.14	56%	100%	0%	224
Rwanda	1.38	9%	3%	0%	185
Mauritania	1.34	2%	100%	66%	381
Swaziland	0.98	15%	100%	59%	1,653
Bhutan	0.4	1%	13%	0%	303

Source: Brown and Lall (2006)

In addition, inappropriate water pricing and subsidised electricity tariffs that encourage the excessive use of groundwater pumping (for agricultural use, for example) also increase vulnerability to changing climatic conditions. For example, 104 of Mexico's 653 aquifers (that provide half the water consumed in the country) drain faster than they can replenish themselves, with 60% of the withdrawals being for irrigation.[25] Similarly, water tables are falling in some drought-affected districts of Pakistan by up to 3 meters per year, with water

[24] Brown and Lall (2006)
[25] International Commission on Irrigation and Drainage (2005)

now available only at depths of 200-300 meters.[26] The consequences of inadequate investment in water-related infrastructure and poor management are important given that most climate change impacts are mediated through water (as discussed in Chapter 3).

Low incomes and underdeveloped financial markets: In many developing countries the capacity of poor people to withstand extreme weather events such as a drought is constrained both by low income levels and by limited access to credit, loans or insurance (in terms of access and affordability).[27] These constraints are likely to become worse as wet and dry seasons become increasingly difficult to predict with climate change.[28] This is often exacerbated by weak social safety nets that leave the poorest people very vulnerable to climate shocks. At the national level, many low-income countries have limited financial reserves to cushion the economy against natural disasters,[29] coupled with underdeveloped financial markets and weak links to world financial markets that limit the ability to diversify risk or obtain or reallocate financial resources. Less than 1% of the total losses from natural disasters, for example, were insured in low-income countries during the period 1985 to 1999.[30]

Poor public services: Inadequate resources and poor governance (including corruption) often result in poor provision of public services. Early warning systems for extreme weather conditions, education programmes raising awareness of climate change, and preventive measures and control programmes for diseases spread by vectors or caused by poor nutrition are examples of public services that would help to manage and cope with the effects of climate change but receive weak support and attention in developing countries.

Implications for future vulnerability of different growth pathways.

The following sections assume current levels of vulnerabilities in the developing world. However, some parts of the developing world may look very different by the end of the century. If development progress is strong, then much of Asia and Latin America may be middle income or above, with substantial progress also being made in Africa. Growth and development should equip these countries to better manage climate change, and possibly avoid some of the most adverse impacts. For example, if there are more resources to build protection against rising sea levels, and economies become more diversified. But the extent to which these countries will be able to cope with climate change will depend on the scale of future impacts, and hence the action today to curb greenhouse gas emissions.

Further, the speed of climate change over the next few decades will - in part - determine the ability of developing countries to develop and grow. Climate change is likely to lead to an increase in extreme weather events.[31] Evidence (discussed below) shows that extreme climate variability can set back growth and development prospects in the poorest countries. If climatic shocks do become more intense and frequent before these countries have been able to reduce their vulnerability, long-term growth potential could be called into question. And some developing countries are already exposed to the damaging impacts of climate change that, in extreme cases such as Tuvalu, have already constrained their long-term development prospects.

[26] Roy (2006)
[27] An estimated 2.5 billion low income people globally do not have access to bank accounts, with less than 20% of people in many African countries having access (compared to 90-95% of people in the developed world) (CGAP, 2004). Poor people are typically constrained by their lack of collateral to offer lenders, unclear property rights, insufficient information to enable lenders to judge credit risk, volatile incomes, and lack of financial literacy, among other things.
[28] The incomes of poor people will become less predictable, making them less able to guarantee the returns that are needed to pay back loans, while insurers will face higher risks and losses making them even less willing to cover those most in need.
[29] IMF (2003)
[30] Freeman et al (2002)
[31] For example, a recent study from the Hadley Centre shows that the proportion of land experiencing extreme droughts is predicted to increase from 3% today to 30% for a warming of around 4°C, and severe droughts at any one time will increase from 10% today to 40% (discussed in Chapters 1 and 3).

4.3 Direct implications of climate change for health, livelihoods and growth: what can be learnt from natural disasters?

The impact of climate change on poor countries is likely to be severe through both the effects of extreme weather events and a longer-term decline in the environment. The impact of previous extreme weather events provides an insight into the potential consequences of climate change.

Many developing countries are already struggling to cope with their current climate. Both the economic costs of natural disasters and their frequency have increased dramatically in the recent past. Global losses from weather related disasters amounted to a total of around $83 billion during the 1970s, increasing to a total of around $440 billion in the 1990s with the number of 'great natural catastrophe' events increasing from 29 to 74 between those decades.[32] The financial costs of extreme weather events represent a greater proportion of GDP loss in developing countries, even if the absolute costs are more in developed countries given the higher monetary value of infrastructure.[33] And over 96% of all disaster related deaths worldwide in recent years have occurred in developing countries. Climatic shocks can - and do - cause setbacks to economic and social development in developing countries. The IMF, for example, estimates costs of over 5% of GDP per large disaster on average in low-income countries between 1997 and 2001.[34]

Climate change will exacerbate the existing vulnerability of developing countries to an often difficult and changing climate. This section focuses on those aspects that will likely feel the largest impacts: health, livelihoods and growth. The analysis draws on evidence from past and current exposure to climate variability to demonstrate the mechanisms at work.

Despite some beneficial effects in colder regions, climate change is expected to worsen health outcomes substantially.

Climate change will alter the distribution and incidence of climate-related health impacts, ranging from a reduction in cold-related deaths to greater mortality and illness associated with heat stress, droughts and floods. Equally the geographic incidence of illnesses such as malaria will change.

As noted in Chapter 3, if there is no change in malaria control efforts, an additional 40 to 60 million people in Africa could be exposed to malaria with a 2°C rise in temperature, increasing to 70 to 80 million at 3 - 4°C.[35] Though some regions such as parts of West Africa may experience a reduction in exposure to vector borne diseases (see Chapter 3), previously unaffected regions may not have appropriate health systems to cope with and control malaria outbreaks. For poor people in slums, a greater prevalence of malaria – or cholera – may lead to higher mortality rates given poor sanitation and water quality, as well as malnutrition. In Delhi, for example, gastroenteritis cases increased by 25% during a recent heat wave as slum dwellers had to drink contaminated water.[36]

The additional heath risks will not only cost lives, but also increase poverty. Malnutrition, for example, reduces peoples' capacity to work and affects a child's mental development and educational achievements with life-long effects. The drought in Zimbabwe in 2000, for

[32] Data extracted from Munich Re (2004). These figures are calculated on the basis of the occurrence and consequences of 'great natural disasters'. This definition is in line with that used by the United Nations and includes those events that over-stretch the ability of the affected regions to help themselves. As a rule, this is the case when there are thousands of fatalities, when hundreds of thousands of people are made homeless or when the overall losses and/or insured losses reach exceptional orders of magnitude. While increases in wealth and population growth account for a proportion of this increase, it cannot explain it all (see Chapter 5 for more details). The losses are given in constant 2003 values.

[33] The true cost of disasters for developing countries is often undervalued. Much of the data on the costs of natural disasters is compiled by reinsurance companies and focused on economic losses rather than livelihood losses, and is unlikely to capture the effect of slow-onset and small-scale disasters and the impact these have on households. Furthermore, the assessments typically do not capture the cumulative economic losses as they are based on snapshots in time. Benson and Clay (2004)

[34] IMF (2003)

[35] Warren et al (2006)

[36] Huq and Reid (2005)

example, is estimated to have contributed to a loss of 7-12% of lifetime earnings for the children who suffered from malnutrition.[37] Managing the consequences of these health impacts can in itself lead to further impoverishment. Households face higher personal health expenditures through clinic fees, anti-malarial drugs and burials, for example. This was seen in the case of Vietnam where rising health expenditures were found to have pushed about 3.5% of the population into absolute poverty in both 1993 and 1998.[38] The effects can be macroeconomic in scale: malaria is estimated to have reduced growth in the most-affected countries by 1.3% per year.[39]

Falling agricultural output and deteriorating conditions in rural areas caused by climate change will directly increase poverty of households in poor countries.

Current experience of extreme weather events underlines how devastating droughts and floods can be for household incomes. For example:

- In North-Eastern Ethiopia, drought induced losses in crop and livestock between 1998 – 2000 were estimated at $266 per household – greater than the annual average cash income for more than 75% of households in the study region;[40]
- In Ecuador the 1997-98 El Niño contributed to a loss of harvest and rise in unemployment that together increased poverty incidence by 10 percentage points in the affected municipalities.[41]

These immediate impacts are often compounded by the rising cost of food - following the drought in Zimbabwe in 1991-92, for example, food prices increased by 72%[42] - and loss of environmental assets and ecosystems that would otherwise provide a safety net for poor people.

These risks and the scale of impacts may increase with climate change if people remain highly exposed to the agricultural sector and have limited resources to invest in water management or crop development. As discussed in Chapter 1, climate change is likely to result in more heatwaves, droughts, and severe floods. In addition to these short-term shocks in output, climate change also risks a long-term decline in agricultural productivity in tropical regions. As Chapter 3 notes, yields of the key crops across Africa and Western Asia may fall by between 15% to 35% or 5% to 20% (assuming a weak or high carbon fertilisation respectively) once temperatures reach 3 or 4°C. Such a decline in productivity would pose a real challenge for the poorest countries, especially those already facing water scarcity. In sub-Saharan Africa, for example, only 4% of arable land is currently irrigated and the effects of climate change may constrain the long-term feasibility of this investment.[43] Some extreme scenarios suggest that by 2100 the Nile could face a decrease in flow of up to 75%,[44] with normal irrigation practices having been found to cease when annual flow is reduced by more than 20%.[45]

Strategies to manage the risks and impacts of an adverse climate can lock people into long-term poverty traps.

The survival strategies adopted by poor people to cope with a changing climate may damage their long-term prospects. Equally, if there is a risk of more frequent extreme weather events, then households may also have shorter periods in which to recover, thus increasing the

[37] Alderman et al (2003)
[38] Wagstaff and van Doorslaer (2003)
[39] These results were estimated after controlling for initial poverty, economic policy, tropical location and life expectancy (using different time frames). Sachs and Gallup (2001)
[40] Carter et al (2004)
[41] Vos et al (1999)
[42] IMF (2003). This was largely due to the higher price of food that had to be imported following a drought induced reduction in agricultural output, as described in Box 4.2, coupled with an increase in inflation to 46%.
[43] Commission for Africa (2005)
[44] Strzepek et al (2001)
[45] Cited in Nkomo et al (2006)

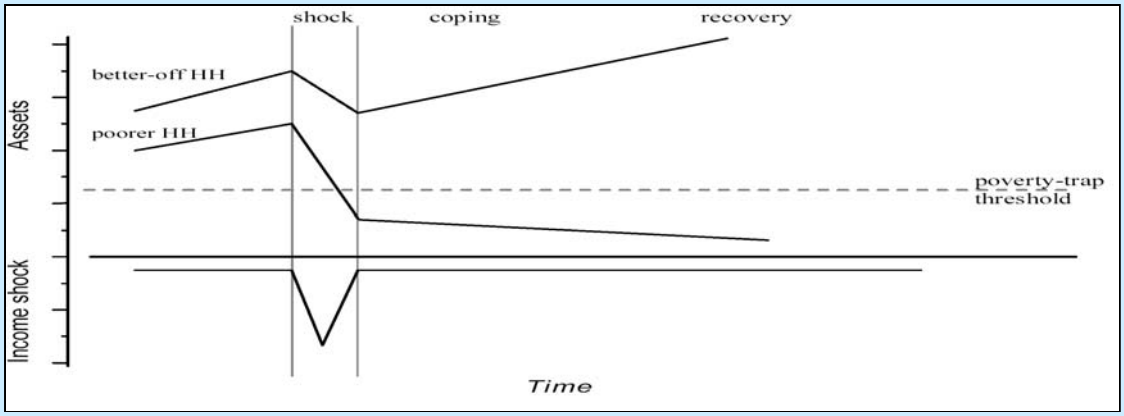
possibility of being pushed into a poverty-trap (as illustrated in Figure 4.4).[46] There are two aspects to this:

- *Risk-managing:* Poor households may switch to low risk crops. In India, for example, poor households have been found to allocate a larger share of land to safer traditional varieties of rice and castor than to riskier but high-return varieties. This response in itself can reduce the average income of these people. Households in Tanzania that allocated more of their land to sweet potatoes (a low return, low risk crop), for example, were found to have a lower return per adult.[47]

- *Risk-coping:* Poor households may also be forced to sell their only assets (such as cattle and land). This can then compromise their long-term prospects as they are unable to educate their children, or raise levels of income over time. Following the 1991-92 droughts in Zimbabwe, many households had to sell their goats that were intended as a form of savings to pay, for example, for secondary education.[48],[49] Alternatively, to try and avoid permanent destitution households may decide to reduce their current consumption levels. This strategy can have long-term effects on health and human capital.[50] Reductions in consumption levels during a drought in Zimbabwe, for example, led to permanent and irreversible growth losses among children - losses that would reduce their future educational and economic achievement.[51]

Figure 4.4 Impact of a climate shock on asset trajectory and income levels

This diagram illustrates: a) the period of shock itself (e.g. hurricanes or drought), b) the coping period in which households deal with the immediate losses created by the shock, and c) the recovery period where a household will try to rebuild the assets they have lost as a result of the climate shock or through the coping strategy they adopted.



Source: Carter et al (2005)

Climate change and variability cuts the revenues and increases the spending of nations, worsening their budget situation.

Dealing with climate change and extreme variability will also place a strain on government budgets, as illustrated in the case of Zimbabwe following the drought of 1991-92 (Box 4.2). The severity of the effect on government revenues will in part depend on the structure of the

[46] This refers to a minimum asset threshold beyond which people are unable to build up their productive assets, educate their children and improve their economic position over time. Carter et al (2005)
[47] Dercon (2003). Households with an average livestock holding in Tanzania were found to allocate 20% less of their land to sweet potatoes than a household with no liquid assets, with the return per adult of the wealthiest group being 25% higher for the crop portfolio compared to the poorest quintile.
[48] Hicks (1993)
[49] A household survey in eight peasant associations in Ethiopia found that distressed sales of livestock following the drought in 1999 sold for less than 50% of the normal price. Carter et al (2004)
[50] People can be pushed below a critical nutritional level whereby no productive activity is possible, with little scope for recovery given dependence on their own labour following the loss or depletion of their physical assets. Dasgupta and Ray (1986)
[51] Hoddinott (2004)

economy. For example, the drought in southern Africa in 1991-92 resulted in a fall in income of over 8% in Malawi where agriculture contributed 45% of GDP at the time, but only 2% of GDP in South Africa where just 5% of GDP was obtained from agriculture.[52] Climate change will also necessitate an increase in spending at the national level to deal with the aftermath of extreme weather events and the consequences of a gradual reduction in food and water supplies. For example, the logistical costs of importing cereal into drought affected southern African countries in 1991-92 alone were $500million.[53] In some cases, the expenditure requirements may be beyond the government's capacity. This was the case following Hurricane Mitch in 1998 where the Honduras government (with a GNP of $850 per capita) faced reconstruction costs equivalent to $1250 per capita.[54]

Box 4.2 Economic Impacts of Drought in Zimbabwe, 1991-92

In late 1991 to early 1992, Zimbabwe was hit by a severe drought. This resulted in a fall in production of maize, cotton and sugarcane by 83%, 72% and 61% respectively; the death/slaughter of more than 23% of the national herd; water shortages that led to the deterioration in quality and price of Zimbabwean tobacco; and reduction in hydro-electricity generation that affected industry and the mineral export sector. The direct impacts of the drought contributed to a doubling of the current account deficit from 6% to 12% of GDP between 1991 and 1992 and an increase in external debt from 36% of GDP in 1991 to 60% in 1992 and 75% by 1995. Government revenues fell in 1992-93 due to drought-induced loss of incomes, slowdown in non-food imports and slow-down in the private sector. Current expenditures increased by 2 percentage points of GDP in 1992-93 due predominantly to drought-related emergency outlays. Government expenditures on health and education were reduced as a share of the budget, in particular for primary education. By the end of 1992, real GDP had fallen by 9% and inflation increased to 46% with food prices having increased by 72%.

At the time of the drought the country was one of the better educated and more functional of states in sub-Saharan Africa. The more recent difficulties with governance, mismanagement and inflation, for example, were not anywhere near as problematic at the time of the drought.

Source: IMF (2003)

When governments face financial constraints, their response to the impacts of climate change and extreme variability – ranging from expenditure switching to additional financing through increasing debt levels - can itself amplify the negative effect on the growth and development of the economy. For example, if key investments to raise economic performance are deferred indefinitely.[55] In reality Official Development Assistance (ODA) will often step in to help fill this financing gap, as was the case in Honduras following Hurricane Mitch for example. However these emergency funds are rarely additional and often reallocated funds or existing commitments within multi-year country programmes brought forward.

The experience of past extreme weather events and episodes testifies to the damaging effect that an adverse climate can have on social and economic prospects in developing countries. If climate change increases the frequency and severity of these events, as the science suggests, the costs on developing countries will grow significantly unless considerable effort is made today to reduce their vulnerability and exposure. And coupled with this will be a longer-term decline in the environment that will have to be managed. This will exert greater pressure still on resources and declines in the productivity and output of climate sensitive sectors.

[52] IMF (2003); World Bank (2006a)
[53] Benson and Clay (2004). Similarly the climatically less severe 1994/95 drought involved costs of US$1 billion in cereal losses (due to higher prices in a tighter international cereal market).
[54] ODI (2005)
[55] IMF (2003)

4.4 What do global climate change models predict for developing countries?

Climate models predict a range of impacts on developing countries from a decrease in agricultural output and food security to a loss of vital river flows. The impacts are predominantly negative.

Evidence from the past and current extreme climate variability demonstrates the effect that a hostile climate can have on development. This section summarises some of the key findings from climate change impact studies undertaken by academics from particular developing regions to contribute to the Stern Review. These reports can be found on the Stern Review website (www.sternreview.org.uk). These summaries are not intended to be comprehensive but are rather more to highlight the key areas where climate change will be seen.

South Asia[56]

- India's economy and societal infrastructures are vulnerable to even small changes in monsoon rainfall. Climate change may increase the intensity of heavy rainfall events (the Mumbai floods of 2005 may be an example)[57] whilst the number of rainy days may decrease. Floods could become more extreme as a result with droughts remaining just as likely. Temperatures will increase for all months. Consequently, during the dry pre-monsoon months of April and May, the incidence of extreme heat is likely to increase, leading to greater mortality.
- Changes in the intensity of rainfall events, and the active / break cycles of the monsoon – combined with an increased risk of critical temperatures being exceeded more frequently – could significantly change crop yields. For example, mean yields for some crops in northern India could be reduced by up to 70% by 2100.[58] This is set against a background of a rapidly rising population that will need an additional 5 million tons of food production per year just to keep pace with the predicted increase in population to about 1.5 billion by 2030.
- Meltwater from Himalayan glaciers and snowfields currently supplies up to 85% of the dry season flow of the great rivers of the Northern Indian Plain. This could be reduced to about 30% of its current contribution over the next 50 years, if forecasts of climate change and glacial retreat are realised. This will have major implications for water management and irrigated crop production, as well as introducing additional hazards to highland communities through increasingly unstable terrain.[59]

Sub-Saharan Africa[60]

- Africa will be under severe pressure from climate change. Many vulnerable regions, embracing millions of people, are likely to be adversely affected by climate change, including the mixed arid-semiarid systems in the Sahel, arid-semiarid rangeland systems in parts of eastern Africa, the systems in the Great Lakes region of eastern Africa, the coastal regions of eastern Africa, and many of the drier zones of southern Africa (see Thornton et al).[61]
- Between 250–550 million additional people may be at risk of hunger with a temperature increase of 3°C, with more than half of these people concentrated in Africa and

[56] Information based largely on Challinor et al (2006). See also Roy (2006)
[57] As ever it is difficult to attribute an outside event to climate change but the evidence is strong that the severity of such events is likely to increase.
[58] Challinor et al (2006). 70% was the maximum reduction in yield that came from the study, in northern regions. Reductions in the 30-60% range were found over much of India. Strictly speaking these results are for groundnut only, although many annual crops are expected to behave similarly. The study was based on an SRES A2 scenario. The values assume no adaptation.
[59] Challinor et al (2006)
[60] Information based largely on Nkomo et al (2006)
[61] The regions at risk of climate change were identified by looking at the possibility of losses in length of growing period that was used as an integrator of changing temperatures and rainfall to 2050. This was projected by downscaling the outputs from several coupled Atmosphere-Ocean General Circulation Models for four different scenarios of the future using the SRES scenarios of the IPCC. Several different combinations of GCM and scenario were used. The vulnerability indicator was derived from the weighted sum of the following four components: 1) public health expenditure and food security issues; 2) human diseases and governance; 3) Human Poverty Index and internal renewable water resources; and 4) market access and soil degradation. (Thornton et al, 2006)

Western Asia.[62] And there are risks of higher temperatures still. Climate change is also predicted to decrease - and/or shift - the areas of suitable climate for 81% to 97% of Africa's plant species. By 2085, 25% - 42% of plant species could find they no longer have any suitable habitat.[63]

- Tens of millions of additional people could be at risk of malaria by the 2080s.[64] Previously unsuitable areas for malaria in Zimbabwe could become suitable for transmission with slight temperature and precipitations variations, whist in South Africa the area suitable for malaria may double with 7.8 million people at risk by 2100.[65]
- Water pressures may be intensified as rainfall becomes more erratic, glaciers retreat and rivers dry up. While there is much uncertainty about flow of the Nile, several models suggest a decrease in river flow, with nine recent climate scenario impacts ranging from no change to more than 75% reduction in flows by 2100.[66] This will have a significant impact on the millions of people that have competing claims on its supplies.
- Many large cities in Africa that lie on or very close to the coast could suffer severe damages from sea level rise. According to national communications to the UNFCCC, a 1 meter sea-level rise (a possibility by the end of the century) could result in the complete submergence of the capital city of Gambia, and losses of more than $470 million in Kenya for damage to three crops (mangoes, cashew nuts and coconuts).[67]

Latin America[68]

- Countries in Latin American and the Caribbean are significantly affected by climate variability and extremes, particularly the ENSO events.[69] The region's economy is strongly dependent on natural resources linked to climate, and patterns of income distribution and poverty exacerbate the impacts of climate change for specific sub-regions, countries and populations.
- Living conditions and livelihood opportunities for millions of people may be affected. By 2055 subsistence farmers' maize production (the main source of food security) in the Andean countries and Central America could fall by around 15% on average, for example, based on projections of HadCM2.[70] The potential die-back, or even collapse, of the Amazon rainforest (discussed in Chapter 3) presents a great threat to the region. The Amazonian forests are home to around 1 million people of 400 different indigenous groups, and provide a source of income and medical and pharmaceutical supplies to millions more.
- Climate change could contribute to a 70% rise in the projected number of people with severe difficulties in accessing safe water by 2025. About 40 million people may be at risk of water supply for human consumption, hydro-power and agriculture in 2020, rising to 50 million in 2050 through the predicted melting of tropical Andean glaciers between 2010 and 2050. The cities of Quito, Lima and La Paz are likely to be most affected. Dengue transmission is likely to increase by 2 to 5 fold by the 2050s in most areas of South America and likely that new transmission areas will appear in the southern half of the continent and at higher elevations.

[62] Cited in Warren *et al* (2006) based on the original analysis of Parry et al. (2004). These figures assume future socio-economic development, but no carbon fertilisation effect, as discussed in Chapter 3.
[63] McClean et al (2005). This is estimated using the Hadley Centre third generation coupled ocean-atmosphere General Circulation Model.
[64] van Lieshout et al (2004)
[65] Republic of South Africa (2000) cited in Nkomo et al (2006)
[66] Strzepek et al (2001)
[67] Gambia (2003) and Republic of Kenya (2002) cited in Nkomo et al (2006)
[68] Information based on Nagy et al (2006)
[69] El Nino-Southern Oscillation events (as discussed in Chapter 1).
[70] Jones and Thornton (2003), cited in Nagy et al (2006)

China[71]

- There is significant variation in climatic patterns across China's regions including arid, temperate and mountainous regions. The average surface air temperature in China has increased by between 0.5 and 0.8°C over the 20th century with increases more marked in North China and Tibetan Plateau compared to southern regions. Temperature rise will lead to temperate zones in China moving north as well as an extension of arid regions. Cities such as Shangai are expected to experience an increase in the frequency and severity of heat waves causing significant discomfort to fast growing urban populations.
- Overall water scarcity is a critical problem in China with existing water shortages, particularly in the north (exacerbated by economic and population growth). Climate change is expected to increase water scarcity in northern provinces such as Ningxia, Gansu, Shanxi and Jilin province. An increase in average rainfall in southern provinces such as Fujian, Zhejiang and Jiangxi is anticipated over the next 50 to 100 years leading to more instances of flooding. From 1988 to 2004, China experienced economic losses from drought and flood equating to 1.2% and 0.8% of GDP respectively.
- Climate change is expected to have mixed effects on agricultural output and productivity across different regions with impacts closely related to changes in water availability. On average, irrigated land productivity is expected to decrease between 1.5% to 7% and rain fed land by between 1.1% to 12.6% under rain- fed conditions from 2020s to 2080s under HadCM2, CGCM1 and ECHAM4 scenarios in China.[72] Overall a net decrease in agriculture production is anticipated with seven provinces in the north and northwest of China particularly vulnerable (accounting for ¼ of total arable land and 14% of China's total agricultural output by value).[73]

Middle East and North Africa

- The region is already very short of fresh water and faces difficulty meeting the needs of fast-growing populations. Most if not all the region may be adversely affected by changing rainfall patterns as a result of climate change. An additional 155 to 600 million people may be suffering an increase in water stress in North Africa with a 3°C rise in temperature according to one study.[74] Yemen is particularly at risk given its low income levels, rapidly growing populations and acute water shortages today. Competition for water within the region and across its borders may grow, carrying the risk of conflict.
- Reduced water availability combined with even modestly higher temperatures will reduce agricultural productivity and in some areas may make crops unsustainable. Maize yields in North Africa, for example, could fall by between 15-25% with a 3°C rise in temperature according to one recent report.[75]
- Some parts of the region – notably the Nile Delta and the Gulf coast of the Arabian peninsula - are in addition vulnerable to flooding from rising sea levels which could lead to loss of agricultural land and/or threats to coastal cities. Others are vulnerable to increased desertification.

Climate change poses a wide range of potentially very severe threats to developing countries. Understanding the impact of climate change on developing countries – at both a regional and national level - is essential to get a better understanding of the scale of threat and urgency of mitigation action, but also to help prepare for some of the now inevitable impacts of climate change. To date, however, analysis undertaken in developing countries of potential threats and impacts has been very limited. Many climate changes are on the way and foresight and action will be crucial if damages to development progress are to be managed both by the private and by public sectors. Further work is required on studying the impacts of climate change on developing countries at a national, regional and global level.

[71] Information based on Erda and Ji (2006)
[72] Tang Guoping et al (2000)
[73] NBSC (2005)
[74] Warren et al (2006)
[75] Warren et al (2006)

4.5 Impact of climate change on economic growth prospects and implications for incomes and health

Over time, there is a real risk that climate change will have adverse implications for growth. This section looks at how income levels and growth have been affected by extreme climate variability and then moves on to summarise illustrative modelling work undertaken as part of the review. If climate change results in lower output and growth levels than would otherwise be the case, there will be implications for poverty levels. But income levels also affect health, and mortality rates will rise above what they would otherwise have been, in addition to any immediate health impacts through illnesses such as malaria. The previous section reviewed a range of projected direct climate impacts on factors affecting lives and livelihoods that recent research has highlighted. This section provides an analysis of their possible impacts on income and health.

Extreme weather events can – and do – affect growth rates in developing countries. Climate change presents a greater threat still.

The output of an economy in a given year depends on labour, environmental quality and capital available in that year (illustrated, for example, in Box 5.1 of Chapter 5). All three will be affected by climate change – be it through the damaging effects on the health and productivity of the labour force, the loss and damage to agriculture and infrastructure, or lower quality investment and capital. As the output and factors of production of an economy are repeatedly affected, so growth prospects will change. This will be particularly true for poorer economies with a stronger focus on agriculture and with less ability to diversify their economies.[76]

The effects of current extreme climate variability demonstrate the potential impact a changing climate can have on output and growth. Changes in the hydrological cycle can be especially damaging. Too much rainfall can inundate transport, for example, limiting trade potential and communication. It has been estimated that the 2000 floods in West Bengal destroyed 450km of rail track and 30 bridges and culverts, and adversely affected 1739km of district roads, 1173km of state highways and 328km of national highways.[77] Too little rainfall will affect crop production but also reduce the flow of surface water that could provide irrigation and hydroelectricity production. The La Niña drought in Kenya, for example, caused damage to the country amounting to 16% of GDP in each of 1998–99 and 1999–2000 financial years, with 26% of these damages due to hydropower losses and 58% due to shortfalls in industrial production.[78]

Economy-wide, multi-market models that incorporate historical hydrological variability project that hydrological variability may cut average annual GDP growth rates in Ethiopia by up to 38% and increase poverty rates by 25%.[79] These models capture the impacts of both deficit and excess rainfall on agricultural and non-agricultural sectors. As climate change increases the variability of rainfall, the scale of these growth impacts could rise significantly.

[76] Increased agricultural productivity has been identified as a key factor in reducing poverty and inequality. This is based on work undertaken by Bourguignon and Morrisson (1998) using data from a broad sample of developing countries in the early 1970s and mid 1980s. Evidence from Zambia, for example, suggests that an extra US$1.5 of income is generated in other businesses for every $1 of farm income. Hazel and Hojjati (1995). Similarly, Block and Timer (1994) estimated an agricultural multiplier in Kenya of 1.64 versus a non-agricultural multiplier of 1.23 in Kenya.

[77] Cited in Roy (2006)

[78] World Bank (2006c)

[79] World Bank (2006c). The model shows growth projections dropping 38% when historical levels of hydrological variability are assumed, relative to the same model's results when average annual rainfall is assumed in all years. Hydrological variability included drought, floods and normal variability of 20% around the mean.

Slower growth could cause an increase in poverty and child mortality relative to a world without climate change, as found by illustrative modelling work undertaken by and for the Stern Review.

The Stern Review has used the PAGE2002 model (an integrated assessment model that takes account of a wide range of risks and uncertainties) to assess how climate change may affect output and growth in the future.[80] Integrated assessment models can be useful vehicles for exploring the kinds of costs that might follow from climate change. However, these are highly aggregative and simplified models and, as such, the results should be seen as illustrative only.

By 2100, under a baseline-climate-change scenario,[81] the mean cost of climate change in India and South East Asia, and in Africa and the Middle East is predicted by PAGE2002[82] to be equivalent to around a 2.5% and 1.9% loss in GDP respectively, compared with what could have been achieved in a world without climate change. Under a high-climate-change scenario,[83] the mean cost of climate change is predicted by PAGE2002 to be 3.5% in India and South East Asia, and 2.7% in Africa and the Middle East.

There are good reasons, however, for giving more emphasis to the higher (95th percentile) impacts predicted in these scenarios, as the model is unlikely to capture the full range of costs to developing countries. In particular:

- The poorest people will be hit the hardest by climate change, an effect for which the highly aggregated models do not allow;
- There are specific effects, such as possible loss of Nile waters and the cumulative effects of extreme weather events (as discussed above), that aggregated global and regional models do not capture;
- This is a long-term story. If emissions continue unabated, temperatures will rise to much higher levels in the next century, committing these regions to far greater impacts (as discussed in Chapters 3 and 6), including the risks associated with mass migration and conflict discussed in the next section;

At the 95th percentile, and under the baseline-climate-change scenario, the projections rise to a 9% loss in GDP in India and South East Asia, and a 7% loss in Africa and the Middle East by 2100. And, under the high-climate-change scenario, the costs of climate change rise significantly to losses of 13% and 10% in GDP respectively (again at 95th percentile).

Given the strong correlation between growth and poverty reduction (see Box 4.3), a climate-driven reduction in GDP would increase the number of people below the $2 a day poverty line by 2100, and raise the child mortality rate compared with a world without climate change. This is illustrated below by modelling work undertaken for the Stern Review. This analysis assumes reductions in poverty and child mortality are driven primarily by GDP growth.[84] As with the PAGE2002 model itself, projections that extend so far into the future should be treated with caution, but are useful for illustrative purposes. The projections summarised below focus only on income effects.

[80] This model picks up the aggregate impacts of climate change on a range of market sectors such as agriculture. The estimates used in this analysis are based on the impact of climate change on market sectors. PAGE2002 allows examination of either market impacts only (as used here to ensure no double counting of poverty impacts) or market plus non-market impacts. These estimates and further details on the PAGE2002 model are given in Chapter 6.

[81] The baseline-climate-change scenario is based largely on scientific evidence in the Third Assessment Report of the IPCC, in which global mean temperature increases to 3.9°C in 2100 (see Chapter 6 for more detail).

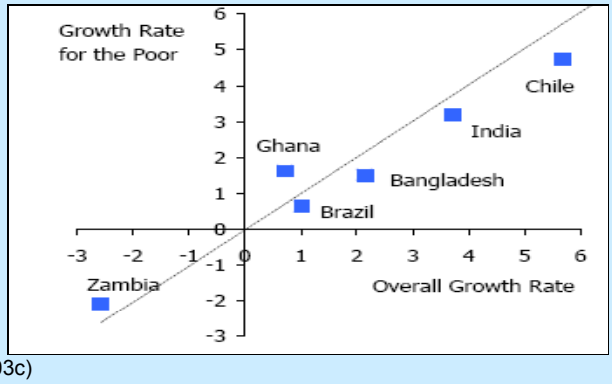
[82] Using the IPCC A2 SRES baseline

[83] In the high-climate-change scenario, global mean temperature increases to 4.3°C in 2100. The high-climate-scenario is designed to explore the impacts that may be seen if the level of temperature change is pushed to higher levels through positive feedbacks in the climate system, as suggested by recent studies (see Chapter 1 and Chapter 6 for more detail).

[84] Other factors – such as changes in income distribution – that may also affect poverty levels or child mortality are assumed to be constant.

Box 4.3 Relationship between growth and development

Countries with higher overall growth rates tend to have higher growth in incomes of poor people. Poverty is estimated to decline on average by 2% for a 1 percentage point rise in economic growth across countries.[85] Kraay estimates that, over the short run, growth accounts for about 70% of the variation in poverty (as measured by a $1 a day poverty line). As the time horizon lengthens, that proportion increases to above 95%.[86] There is a close relationship between growth and many non-income indicators of development, ranging from under-five mortality to educational attainment and peace and security. Income-earning opportunities provide citizens with a vested interest in avoiding conflict, and security allows governments to invest in productive assets and social expenditures, rather than defence. East Asia has grown rapidly (5.8% in the 80s and 6.3% in the 90s) and has seen the fastest fall in poverty in human history. An annual growth of more than 7% will be needed to halve severe poverty in Africa by 2015 (and a 5% annual growth is required just to keep the number of poor people from rising).[87]



zSource: World Bank (2003c)

While growth is clearly an important contributor to poverty reduction, much depends on how the benefits of this growth are distributed and the extent to which the additional resources generated are used to fund public services such as healthcare and education. Poor people benefit the most from economic growth when it occurs in those parts of the economy that offer higher returns for poor people's assets.

Poverty projections

By 2100, climate change could cause an additional 145 million people to be living on less than $2 a day in South Asia and sub-Saharan Africa (100 million people and 45 million people respectively) because of GDP losses alone at the 95th percentile of the baseline-climate-change scenario and runs, or 35 million people at the mean of these runs.

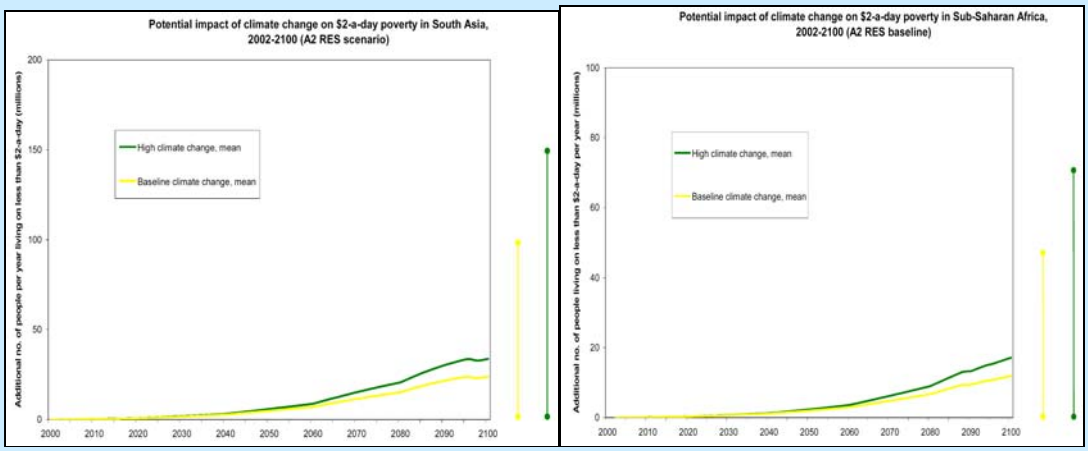
Under the high-climate-change scenario at the 95th percentile, up to an additional 220 million people could be living on less than $2 a day in South Asia and sub-Saharan Africa (150 million people and 70 million people respectively), because of GDP losses alone. The effects at the mean of the distribution are smaller but still significant: up to an additional 50 million people living on less than $2 a day per year.

These projections are illustrated in Box 4.4 below. If growth proceeds faster than predicted, then the overall numbers of people living on below $2 per day will be less, while if it is slower, there will be more people pushed into poverty. These calculations should be viewed as indicative of the risks.

[85] Ravallion (2001)
[86] Kraay (2005)
[87] World Bank (2000)

Box 4.4 Potential impact of climate change on additional people living on less than $2 a day in South Asia and sub-Saharan Africa

These projections are calculated using the formulae for the poverty headcount used in World Bank calculations,[88] population forecasts, and the assumptions that average household income grows at 0.8 times the rate of GDP per capita[89] and distribution of income remains constant.



Source: Anderson (2006)

Child mortality projections

There is also a well-studied relationship between reduced income and child mortality. Falling income and GDP levels from what could have been achieved in a world without climate change will slow the improvement of child (and adult) health in developing countries.[90] Lower per capita expenditures are likely on goods that improve health, such as safe water, food and basic sanitation at both a public and private level. Previous econometric studies have reported a range of values for the income elasticity of infant and child mortality, the vast majority falling between –0.3 and –0.7. Taking an elasticity of 0.4, for example, implies that a 5% fall in GDP from what could have been achieved in a world without climate change will lead to a 2% increase in infant mortality.[91] This analysis uses a value of -0.5 for the elasticity of the child mortality rate (deaths per 1,000 births) with respect to per capita income, the mid-point of this range.[92]

Using the illustrative output and growth scenarios generated by PAGE2002, climate change could cause an additional 40,000 (mean) to 165,000 (95th percentile) child deaths per year in South Asia and sub-Saharan Africa through GDP losses alone under the baseline-climate-change scenario.

Under the high-climate-change scenario, climate change could cause an additional 60,000 (mean) to 250,000 (95th percentile) child deaths per year by 2100 in South Asia and sub-

[88] The formulae express the level of poverty as a function of the poverty line, average household income and the distribution of income. The $2 poverty line is used throughout.

[89] This figure is obtained from a cross-country regression of rates of growth in mean household expenditure per capita on GDP per capita. Ravaillion (2003)

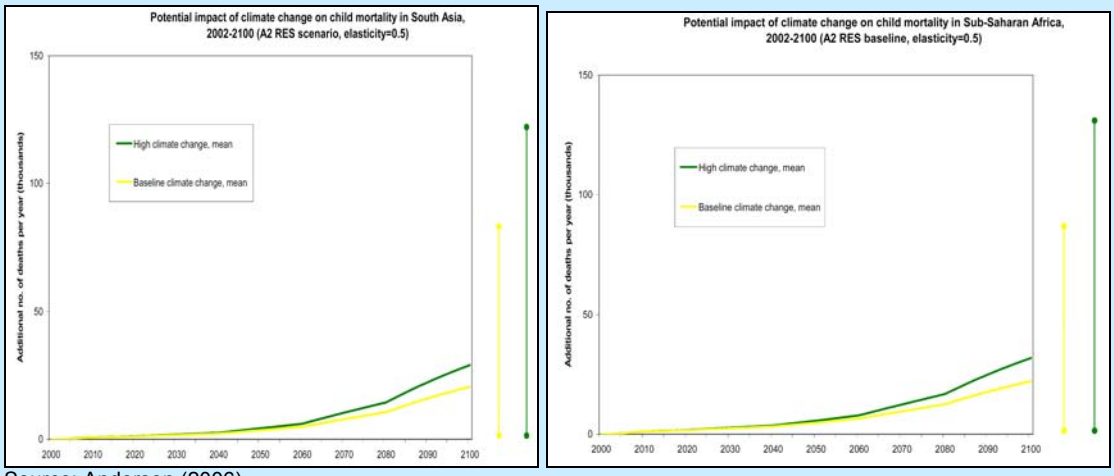
[90] It is important to note that income alone does not determine health outcomes, efficient public programmes and access to education for women are also important factors, for example. Furthermore, the way in which GDP per capita changes (for example if there is a change in the distribution of income that coincides with the change in national income) can affect the impact it has on health.

[91] Analysis demonstrates the health effects today of slowing or negative per capita growth. For example, in 1990, over 900,000 infant deaths would have been prevented had developing countries been able to maintain the same rate of growth in the 1980s as in the period 1960-80 (assuming an elasticity of -0.4), rather than the slow or negative growth they in fact experienced. The effects were particularly significant in African and Latin America, where growth was lower by 2.5% on average (Pritchett and Summers, 1993).

[92] The elasticity is assumed to be a constant across countries and over time, consistent with econometric evidence (such as Kakwani (1993)). However, the average elasticity of child mortality with respect to GDP over a period of time will typically not be the same as the actual elasticity that applies on a year-to-year basis, even if the latter is assumed constant, because of compounding.

Saharan Africa through GDP losses alone 2100, and compared with a world without climate change. These projections are illustrated in Box 4.5 below.

Box 4.5 Potential impact of climate change on additional child deaths per year in South Asia and sub-Saharan Africa



Source: Anderson (2006)

The above projections pick up the pure income effect of climate change on poverty and child mortality through its dampening effect on GDP, and do *not* include the millions of people that will be exposed to heat stress or malaria, or risk losing their jobs, assets and livelihoods through extreme weather events, for example, as discussed in Section 4.3. This analysis and projections are simply illustrative of possible risks associated with a loss in income through climate change.

4.6 Population movement and risk of conflict

Greater resource scarcity, desertification, risks of droughts and floods, and rising sea levels could drive many millions of people to migrate – a last-resort adaptation for individuals, but one that could be very costly to them and the world.

The impacts of climate change, coupled with population growth in developing countries, will exert significant pressure for cross-border and internal population movement. There is already evidence of the pressure that an adverse climate can impose for migration. Approximately 7 million people migrated in order to obtain relief food out of the 80 million considered to be semi-starving in sub-Saharan Africa primarily due to environmental factors.[93]

Millions of people could be compelled to move between countries and regions, to seek new sources of water and food if these fall below critical thresholds. Rising sea levels may force others to move out of low-lying coastal zones. For example, if sea levels rise by 1 metre (a possible scenario by the end of the century, Chapter 3) and no dyke enforcement measures are taken, more than one-fifth of Bangladesh may be under water for example.[94] And atolls and small islands are at particular risk of displacement with the added danger of complete abandonment. As one indication of this, the government of Tuvalu have already begun negotiating migration rights to New Zealand in the event of serious climate change impacts.[95]

The total number of people at risk of displacement or migration in developing countries is very large. This ranges from the millions of people at risk of malnutrition and lack of clean water to those currently living in flood plains. Worldwide, nearly 200 million people today live in coastal flood zones that are at risk; in South Asia alone, the number exceeds 60 million people.[96] In

[93] Myers (2005)
[94] Nicholls (1995) and Anwar (2000/2001)
[95] Barnett and Adger (2003)
[96] Warren *et al.* (2006) analysing data from Nicholls (2004), Nicholls and Tol (2006) and Nicholls and Lowe (2006). This is calculated on the basis of the number of people that are exposed each year to storm surge elevation that has

addition, there are potentially between 30 to 200 million people at risk of hunger with temperature rises of 2 to 3°C – rising to 250 to 550 million people with a 3°C warming;[97] and between 0.7 to 4.4 billion people who will experience growing water shortages with a temperature rise of 2°C,[98] as discussed in Chapter 3.

The exact number of people who will actually be displaced or forced to migrate will depend on the level of investment, planning and resources at a government's disposal to defend these areas or provide access to public services and food aid. The Thames Barrier, for example, protects large parts of London. In Shanghai and Tokyo, flood defences and pumped drainage prevent flooding of areas lying below normal tides.

Protection is expensive, however, particularly relative to income levels in developing countries. A project to construct 8,000 kilometres of river dykes in Bangladesh – a country with a GNI of $61 billion - is costing $10 billion. These high costs will discourage governments from investing. Defensive investments must be made early to be effective, but they may be politically unpopular if they would divert large amounts of money from programmes with more immediate impact such as infrastructure, health and education.

Drought and other climate-related shocks may spark conflict and violence, as they have done already in many parts of Africa.

The effects of climate change - particularly when coupled with rapid population growth, and existing economic, political, ethnic or religious tensions - could be a contributory factor in both national and cross-border conflicts in some developing countries.

- Long-term climate deterioration (such as rising temperatures and sea levels) will exacerbate the competition for resources and may contribute to forced dislocation and migration that can generate destabilising pressures and tensions in neighbouring areas.

- Increased climate variability (such as periods of intense rain to prolonged dry periods) can result in adverse growth shocks and cause higher risks of conflict as work opportunities are reduced, making recruitment into rebel groups much easier. Support for this relationship has been provided by empirical work in Africa, using rainfall shocks as an instrument for growth shocks.[99]

Adverse climatic conditions already make societies more prone to violence and conflict across the developing world, both internally and cross-border. Long periods of drought in the 1970s and 1980s in Sudan's Northern Darfur State, for example, resulted in deep, widespread poverty and, along with many other factors such as a breakdown in methods of coping with drought, has been identified by some studies as a contributor to the current crisis there.[100] Whilst climate change can contribute to the risk of conflict, however, it is very unlikely to be the single driving factor. Empirical evidence shows that a changing and hostile climate has resulted in tension and conflict in some countries but not others. The risk of climate change sparking conflict is far greater if other factors such as poor governance and political instability, ethnic tensions and, in the case of declining water availability, high water interdependence are already present. In light of this, West Africa, the Nile Basin and Central Asia have been identified as regions potentially at risk of future tension and conflict. Box 4.6 indicates areas vulnerable to future tension and past conflicts where an adverse climate has played an important role.

a one in a thousand year chance of occurring. These odds and the numbers explored could be rising rapidly. This has already been demonstrated in the case of heat waves in Southern Europe where the chance of having a summer as hot as in 2003 that in the past would be expected to occur once every 1000 years, will be commonplace by the middle of the century due to climate change, as discussed in Chapter 5.

[97] Warren et al. (2006) based on the original analysis of Parry *et al.* (2004).

[98] Warren et al. (2006) based on the original analysis of Arnell (2004) for the 2080s.

[99] Miguel et al (2004), Collier and Hoeffler (2002), Hendrix and Glaser (2005) and Levy et al (2005)

[100] University for Peace Africa Programme (2005)

Box 4.6 Future risks and past conflicts

Future risks

- *West Africa:* Whilst there is still much uncertainty surrounding the future changes in rainfall in this part of the world, the region is already exposed to declining average annual rainfall (ranging from 10% in the wet tropical zone to more than 30% in the Sahelian zone since the early 1970s) and falling discharge in major river systems of between 40 to 60% on average. Changes of this magnitude already give some indication of the magnitude of risks in the future given that we have only seen 0.7°C increase and 3°C or 4°C more could be on the way in the next 100 to 150 years. The implications of this are amplified by both the high water interdependence in the region - 17 countries share 25 transboundary watercourses – and plans by many of the countries to invest in large dams that will both increase water withdrawals and change natural water allocation patterns between riparian countries.[101] The region faces a serious risk of water-related conflict in the future if cooperative mechanisms are not agreed.[102]

- *The Nile:* Ten countries share the Nile.[103] While Egypt is water scarce and almost entirely dependent on water originating from the upstream Nile basin countries, approximately 70% of the Nile's waters flow from the Ethiopian highlands. Climate change threatens an increase in competition for water in the region, compounded by rapid population growth that will increase demand for water. The population of the ten Nile countries is projected to increase from 280 million in 2000 to 860 million by 2050. A recent study by Strzepek et al (2001) found a propensity for lower Nile flows in 8 out of 8 climate scenarios, with impacts ranging from no change to a roughly 40% reduction in flows by 2025 to over 60% by 2050 in 3 of the flow scenarios.[104] Regional cooperation will be critical to avoid future climate-driven conflict and tension in the region.

Past conflicts

- *National conflict*: Drought in Mali in the 1970s and 1980s damaged the pastoral livelihoods of the semi-nomadic Tuareg. This resulted in many people having to seek refuge in camps or urban areas where they experienced social and economic marginalisation or migrated to other countries. On their return to Mali, these people faced unemployment and marginalisation which, coupled with the lack of social support networks for returning migrants, continuing drought and competition for resources between nomadic and settles peoples (among many other things), helped create the conditions for the 'Second Tuareg Rebellion' in 1990. A similar scenario has played out in the Horn of Africa,[105] and may now be replicating itself in northern Nigeria, where low rainfall combined with land-use pressures have reduced the productivity of grazing lands, and herders are responding by migrating southward into farm areas.[106]

- *Cross-border conflict:* Following repeated droughts in the Senegal River Basin in the 1970s - 80s, the Senegal River Basin Development Authority was created by Mali, Mauritania and Senegal with the mandate of developing and implementing a major water infrastructure programme. Following the commissioning and completion of agreed dams, conflict erupted between Senegal and Mauritania when the river started to recede from adjacent floodplains. The dispute and tension escalated with hundreds of Senegalese residents being killed in Mauritania and a curfew imposed by both Governments such that 75,000 Senegalese and 150,000 Mauritanians were repatriated by June 1989. Diplomatic relationships between the two countries were restored in 1992, but a virtual wall has effectively been erected along the river.[107] Drought has also caused conflict between

[101] For example, there are 20 plans in place to build large dams along the Niger River alone.
[102] Niasse (2005)
[103] Ethiopia, the Sudan, Egypt, Kenya, Uganda, Burundi, Tanzania, Rwanda, the Democratic Republic of Congo and Eritrea.
[104] Strzepek et al (2001). Whilst there is general agreement regarding an increase in temperature with climate change that will lead to greater losses to evaporation, there is more uncertainty regarding the direction and magnitude of future changes in rainfall. This is due to large differences in climate model rainfall predictions.
[105] Meier and Bond (2005)
[106] AIACC (2005)
[107] Niasse (2005)

Ugandan and Kenyan pastoralists, and has led Ethiopian troops to move up north to stop the Somalis crossing the border in search of pasture and water for their livestock.[108] Similarly, extreme weather events in 2000 that affected approximately 3 million people in Bangladesh resulted in migration and violence as tribal people in North India clashed with emigrating Bangladeshis.[109]

4.7 Implications of Climate Change on other Aspects of Development

All development aspirations could be affected by climate change. Education and gender goals, for example, will be at risk to the effects of climate change, in turn further amplifying vulnerability to the impacts of climate change (as discussed in Box 4.7). Limited research has been undertaken on the impact of climate change to date on these important aspects of development. This merits much greater attention going forward.

Box 4.7 Impact of Climate change on Education and Gender Equality

Education

Climatic disasters can threaten educational infrastructure making it physically impossible for children to attend school. For example in 1998 Hurricane Mitch destroyed 25% of Honduras' schools.[110] Education levels may also decline through climate-induced changes in income and health conditions. Schooling will become less affordable and accessible, especially for girls, as income, assets and employment opportunities are affected by climate change. Children will need to help more with household tasks or prematurely engage in paid employment leaving less time for schooling. Deteriorating health conditions will also affect both a child's learning abilities and school attendance, and the supply of teachers. Children will be deprived of the long-term benefits of education and be more vulnerable to the effects of climate change. Better-educated farmers, for example, absorb new information quickly, use unfamiliar inputs, and are more willing to innovate. An additional year of education has been associated with an annual increase in farm output of between 2 to 5%.[111]

Gender equality

Gender inequalities will likely worsen with climate change. Workloads and responsibilities such as collecting water, fuel and food will grow and become more time consuming in light of greater resource scarcity. This will allow less time for education or participation in market-based work. A particular burden will be imposed on those households that are short of labour, further exacerbated if the men migrate in times of extreme stress leaving women vulnerable to impoverishment, forced marriage, labour exploitation and trafficking.[112] Women are 'over-represented' in agriculture and the informal economy, sectors that will be hardest hit by climate change. This exposure is coupled with a low capacity to adapt given their unequal access to resources such as credit and transport. Women are also particularly vulnerable to the effects of natural disasters with women and children accounting for more than 75% of displaced persons following natural disasters.[113]

4.8 Conclusion

The impacts of climate change will exacerbate poverty – in particular through its effects on health, income and future growth prospects. Equally, poverty makes developing countries more vulnerable to the impacts of climate change. This chapter has discussed some of the specific risks faced by developing countries. However it is the sum of the parts that creates perhaps the greatest concern. Poor households and governments may, for example, face falling food and water supplies that will increase poverty directly, while also facing greater health risks - for example, through malaria or as a result of extreme weather events. These impacts may be compounded if governments' have limited – or reduced - financial resources

[108] Christian Aid (2006)
[109] Tanzler et al (2002)
[110] ODI (2005)
[111] This takes into account farm size, inputs, hours worked etc. This is drawing on evidence from Malaysia, Ghana and Peru Information drawn from Birdsall (1992)
[112] Chew and Ramdas (2005)
[113] Chew and Ramdas (2005)

to manage these impacts, and to invest in building resilience against the future impacts of climate change. An important priority for future research will be to identify the type and scale of climate change impacts on developing countries and to understand more deeply the nature of these compounding, aggregated effects.

The threats posed by climate change increase the urgency of promoting growth and development today. This is key to reducing the vulnerability of developing countries to some of the now inevitable impacts of climate change, and enabling them to better manage these impacts. But adaptation can only mute the effects and there are limits to what it can achieve.

Unchecked, climate change could radically alter the prospects for growth and development in some of the poorest countries. This underlines the urgency of strong and early action to reduce greenhouse gas emissions. This is discussed further in part III of the report.

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