DRAFT

Responding to Climate Change in South Asia

June 12, 2009

South Asia Region

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Chapter 1. Climate Change: The Global Context

An Issue of Global Concern

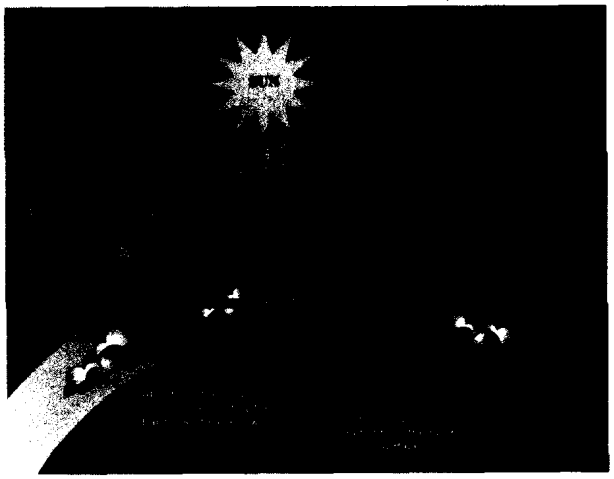
Climate change is not a new phenomenon – it has been a feature of planet Earth throughout much of its history. Yet in recent decades it has come to the forefront of global attention, for three main reasons: the unprecedented speed of climate change today; the growing certainty that this rate of change is largely the result of human activities; and the scale of the disaster that could afflict humanity should projections prove accurate. And evidence is mounting that the changes to climate could be irreversible without immediate action.

Causes of Present-Day Climate Change

Crucially, this current period of climate change, characterized by rapid global warming, has coincided with the modern industrial era. Human activities, such as the burning of fossil fuels and deforestation, have increased the quantities of heat-trapping "greenhouse gases" in the atmosphere, especially carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), creating a "greenhouse effect" of global warming (Box 1.1). The 1990s was the warmest decade, and 2005 the warmest year, on record since 1800. The impacts of higher temperatures are already being felt and will continue to intensify. Climate change is a problem that the world will have to confront (National Academies 2008).

Box 1.1 What Is the Greenhouse Effect?

Certain naturally occurring gases, such as CO_2 and water vapor, allow the passage of incoming short-wave radiation while trapping much of the long-wave radiation reflected from the Earth's surface, in much the same way as a greenhouse operates (see figure). As the volume of these "greenhouse gases" increases, so too does the Earth's temperature. This phenomenon of global warming is critically altering climate systems, with far-reaching impacts on ecosystems and human systems. The interrelationships are extremely complex and difficult to model.



Source: IPCC 2007a. *[Figure FAQ 1.3].*

Not surprisingly, given the range of factors that influence climate, there has been intense controversy over the extent to which these changes have resulted from human activities. However, the weight of evidence is now indisputable, and recent work by the Intergovernmental Panel on Climate Change (IPCC) indicates that the best agreement between model simulations and observations over the past 140 years occurs when human factors are added to natural factors (Box 1.2).

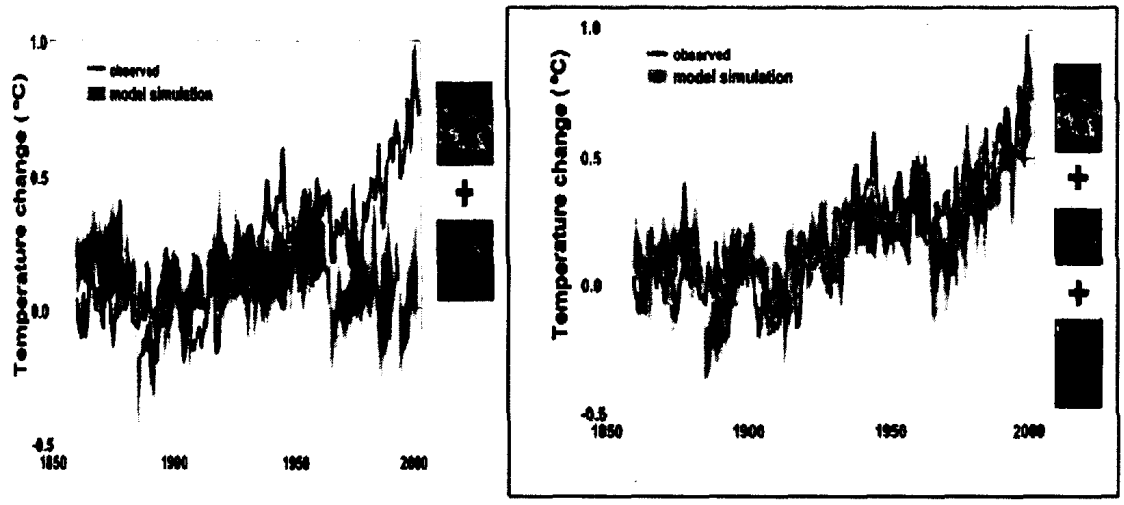
Data from the ice cores in Antarctica provide compelling evidence of the greenhouse effect. Natural archives of Earth's past climate come in many forms – the sea bed, tree rings, peat bogs

and glaciers. But the records locked up in the large polar ice sheets are especially valuable and provide verifiable evidence of the reliability of climate models. Ice cores drilled deep into the polar ice mass unravel information on past temperatures, precipitation, volcanic activity, solar activity and atmospheric gases (Box 1.2). In the past 440,000 years bp (before the present), periods of elevated greenhouse gases have been accompanied by higher atmospheric temperatures. Historically the temperature and CO_2 changes have oscillated around a stable core, with cycles of around 100,000 year intervals between cold (warm) spells. Current levels and increases in greenhouse gases far exceed these historic emissions, suggesting the possibility of unprecedented temperature changes (Box 1.2).

The emissions that drive climate change are ubiquitous and derive from almost every economic activity – energy production and use, transport, agriculture, and deforestation. Energy-related emissions (from production, transformation, and consumption) account for over 65 percent of greenhouse gas emissions, followed by deforestation[1], which contributes about 18 percent, with the remainder from agriculture and wasteland use (Figure 1.1). Deforestation and fossil fuel consumption primarily produce CO_2, while agriculture and waste are the main sources of methane emissions.

Box 1.2 Human Activities and Global Warming

Human activities have changed the climate of the Earth, as shown in the figures below. In the left panel the temperature projections are based on natural accumulations of greenhouse gases only, and exclude anthropogenic (human-produced) greenhouse gases. There is a wide divergence between observed and projected temperature changes. In the right panel anthropogenic greenhouse gases are added to the model simulation, producing a remarkable convergence with observed temperature changes.



Source: IPCC 2007a.

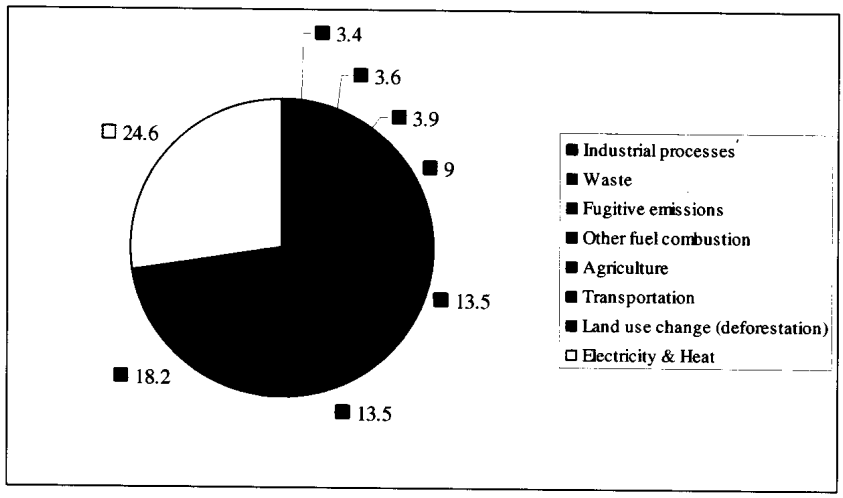
This is one of several pieces of evidence suggesting anthropogenic culpability. The pattern of warming is also consistent with the greenhouse effect with greater temperature increases over

[1] Trees and soil absorb and store carbon. Deforestation not only causes the loss of these carbon storehouses, but it also sends the carbon it had been storing back into the atmosphere, increasing total carbon emissions.

land and in the Arctic than the oceans.

In addition, data from ice cores drilled from the Antarctica show that current CO_2 levels are higher than they have been in 440,000 years and variations in CO_2 correlate with surface temperatures. The polar ice cores provide unique evidence because the air trapped in the ice provides measurable evidence of past atmospheric greenhouse gases, while the isotopes in the water provide information on the surface temperature at that time. There is a remarkably close correlation between Antarctica temperatures and atmospheric concentrations of CO_2 and CH_4. Historically, greenhouse gas concentrations have oscillated in a stable bound between 180 to 280 parts per million (ppm). Each dip in CO_2 in the past million years has been accompanied by a cold spell and this has occurred approximately every 100,000 years. The current increase in greenhouse gases is unprecedented in both magnitude and rate of change. The increase in the last 100 years is roughly equivalent to the entire increase that occurred in the past 100,000 years, suggesting that temperature increases could exceed bounds previously experienced by humanity (Petit *et al* 2003).

Figure 1.1 Sources of Greenhouse Gas Emissions



Source: World Resources Institute 2005.

Looking at sources of greenhouse gases by country and region, developed countries, not surprisingly, are largely responsible for the historical build-up of greenhouse gases and still emit, in total, slightly more than developing countries. The United States ranks as the highest contributor to cumulative CO_2 emissions (with a share of 29 percent), followed by the countries of the present European Union (26 percent).[2] Overall, developing countries have contributed only 24 percent to historical emissions, but their emissions are currently rising more rapidly than those of developed countries.

[2] These figures are based on emissions from 1850 to 2002.

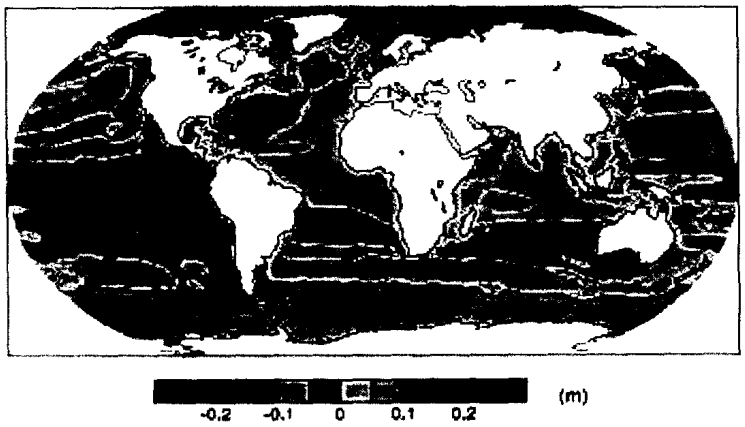
Consequences of Climate Change

As a result of climate change, the world will have to confront a wide variety of readjustments in physical systems that will, in turn, have an array of human, economic, and social consequences.

Physical Consequences of Climate Change

The warmer surface temperatures associated with climate change will have a number of physical consequences, several of which are already occurring. Sea levels rose globally by 10–20 millimeters during the 20th century, and will continue to rise (Figure 1.2). The planet's storage of solid water is rapidly declining. Snow cover has receded by about 10 percent since the 1960s, and many of the world's alpine and continental glaciers are retreating. In the Arctic, where the expanding ocean absorbs more heat, the ice cover has retreated faster than the global average. Science predicts that at current trends summers in the Arctic may be ice free within 100 years. Projections suggest that there will also be an increase in the frequency and duration of extreme weather events, including floods, droughts, and storms.

Figure 1.2 Sea Level Rise in 2080–2099 from 1980–1999



Note: Local sea level change (meters) due to ocean density and circulation change relative to the global average (i.e., positive values indicate greater local sea level change than global) during the 21st century, calculated as the difference between averages for 2080 to 2099 and 1980 to 1999, as an ensemble mean of over 16 atmosphere-ocean general circulation models forced with the *Special Report on Emissions Scenarios* (SRES) A1B scenario. Stippling denotes regions where the magnitude of the multi-model ensemble mean divided by the multi-model standard deviation exceeds 1.0 (Nakicenovic and Swart 2000).

Source: IPCC 2007a.

While these impacts are apparent and measurable, the economic consequences would be much more complex, with cascading impacts involving a bewildering array of factors and mechanisms (Stern 2006). Effects will vary across the globe, with some areas, such as the Sahel, the Mediterranean, Southern Africa, and parts of Southern Asia, projected to become drier due to more heat and evaporation, while other areas, particularly the east of North and South America, Northern Europe, and Northern and Central Asia, would experience increased and more variable precipitation.

Human and Economic Implications of Climate Change

Climate change will have wide-ranging impacts on human development. Agriculture is a particularly climate-sensitive sector. Projections suggest that initially the colder temperate regions (of Northern Europe, Russian Federation, and Canada) could reap short-term gains through higher agricultural yields due to rising temperatures (Cline 2007). But most developing countries located in the warmer regions would be impacted negatively, especially where crops are already at the limit of their climate tolerance, or where rangeland-based pastoralism is practiced on marginal pastures.

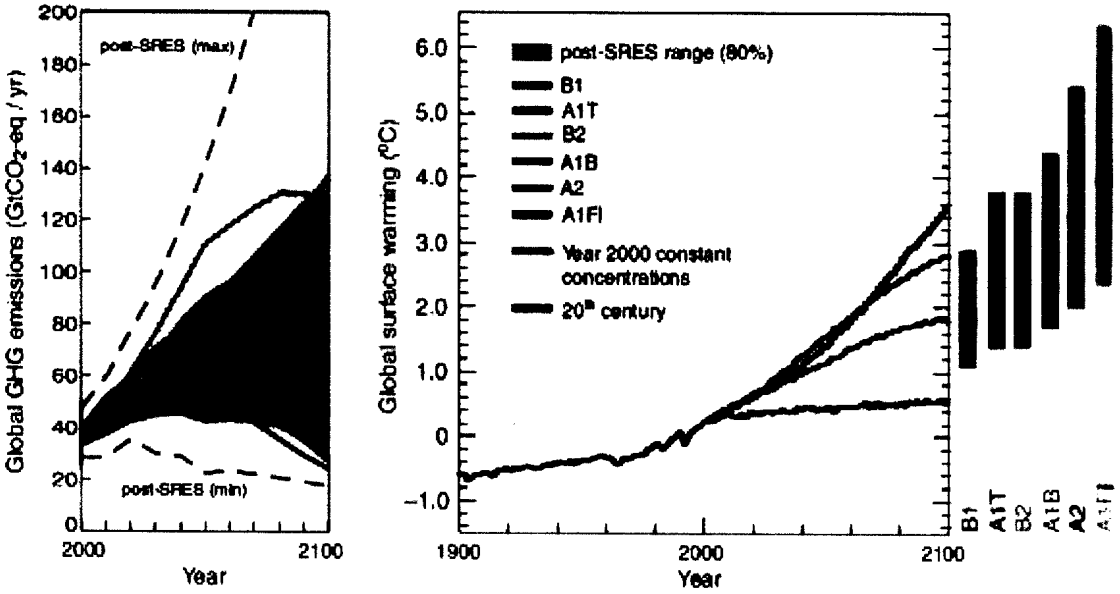
Water insecurity will probably worsen, particularly in the arid and semi-arid zones, which will face diminishing water supplies, further jeopardizing agriculture and livelihoods. Additionally, the retreat of glaciers and melting of snow cover will pose risks of flooding in low-lying areas and reduce water availability and seasonal flows in the long term. Coastal communities face a slower and more insidious threat as the rise in sea level gradually engulfs the most low-lying areas. The increase in extreme weather events will be a further shock to the already vulnerable economies of developing nations.

Climate change may have implications for human health. Many of the major vectors for diseases such as cholera, Rift Valley fever, diarrhea, malaria, and dengue are highly climate sensitive and could become more pervasive with rising temperatures. In poor communities, the indirect effects caused by declining farm yields and food availability could lead to malnutrition and a heightened susceptibility to other diseases. Finally, changing climate patterns will have largely unpredictable effects on ecosystems and biodiversity, with implications for human livelihoods.

What of the Future? Climate Change Projections and Impacts

To compare possible outcomes, IPCC developed a variety of greenhouse gas emissions scenarios (Nakicenovic and Swart 2000) that span a range of plausible development pathways and possibilities (Figure 1.3). In all scenarios, global surface temperatures will continue to rise – the degree of warming depends largely on the extent to which global greenhouse gas emissions are controlled during the coming century. Figure 1.4 maps projected global warming patterns in three of the scenarios, from the optimistic scenario involving an average rise in temperature of about 0.6°C to the more pessimistic scenario with an average temperature increase of over 5°C, with potentially calamitous impacts on climate systems and natural resource productivity. Climate change is often viewed as a problem for the future. However, the maps in figure 1.4 suggest that some changes are projected to occur as early as 2020, regardless of mitigation actions. Avoiding the negative effects of climate change will therefore require immediate adaptive responses.

Figure 1.3 Projected Greenhouse Gas Emissions and Global Surface Warming

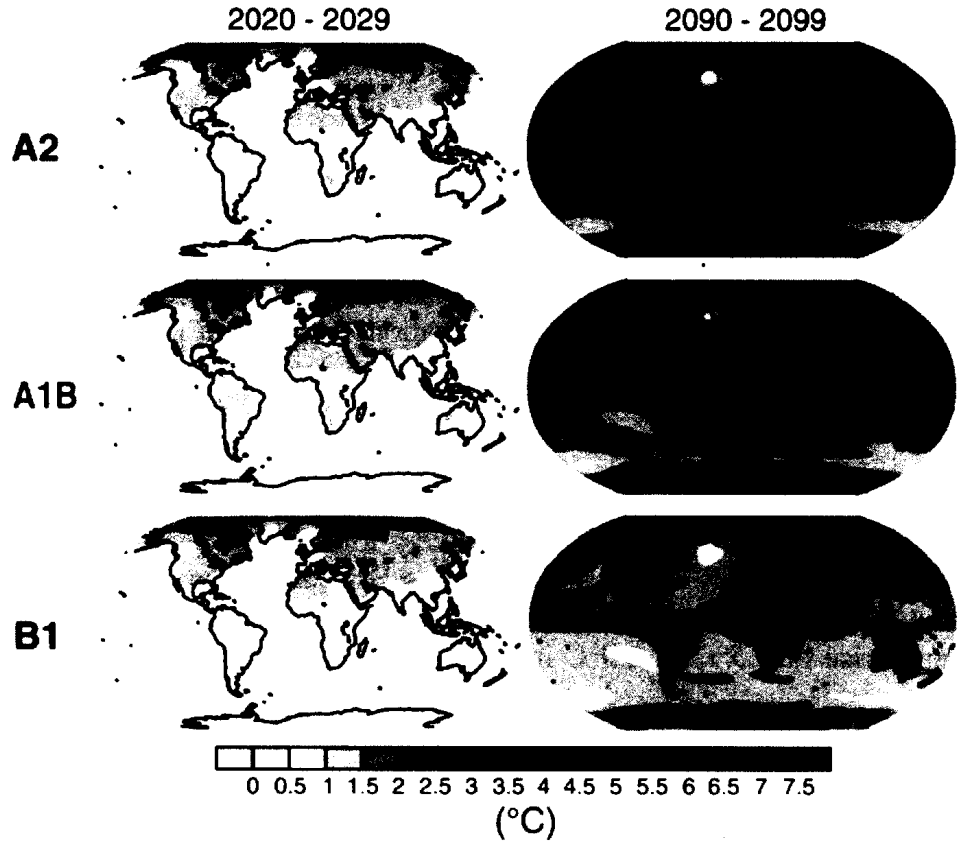


Note: The solid lines are averages across different models for different scenarios relative to baseline average temperatures (1980–1990), while the bars illustrate the likely range of outcomes for each scenario.

SRES: *Special Report on Emissions Scenarios* (Nakicenovic and Swart 2000).

Source: IPCC 2007a. *[Figure SPM5]*

Figure 1.4 Projected Warming 2020–2099



Note: Atmosphere-ocean general circulation model (AOGCM) projections of surface warming: projected surface temperature changes for the early and late 21st century relative to the period 1980–1999. The panels show the multi-AOGCM average projections for the A2 (top), A1B (middle), and B1 (bottom) SRES scenarios averaged over decades 2020–2029 (left) and 2090–2099 (right).

Source: IPCC 2007b. *[Figure 3.2].* Reproduced/modified with permission from IPCC.

Adapting economic and social systems to cope with such changes presents a daunting policy problem. At the most fundamental level, climate change is a global issue, necessitating an international response. But there is great variability in levels of responsibility for climate change, in the degree to which countries are affected, and in their capacity to respond, with developing countries being most severely stretched and developed countries burdened with exploding fiscal deficits. There is a further temporal asymmetry that makes agreements difficult to reach. The costs of controlling emissions weigh heavily upon current generations, while many of the benefits of addressing the problem accrue in the uncertain and distant future. Climate change thus presents an unprecedented test of humanity's ethical values and commitment to the future health of the planet and all of its inhabitants.

Chapter 2. How Will South Asia's Climate Change?

Projecting climate futures is a complex task, involving many unknowns and uncertainties. Changes will depend on the uncertain path of future greenhouse gas emissions. Even if these emission trajectories were known, eventual impacts depend on the complex response of physical systems to emission changes and fragile feedback loops. While acknowledging the many challenges in projecting scenarios, a broad scientific consensus has emerged on the likely changes in the primary climate variables: temperature, precipitation, runoff, sea level rise, and glacier melt.

Temperature

There is general agreement that the world is warming. There is ample evidence that by mid-century temperature increases ranging from 1°C to 2°C are likely to occur. In South Asia this warming will vary regionally, with already warm areas such as Sri Lanka and the Maldives seeing the lowest rise (about 1°C), while the higher altitude areas of Afghanistan, Bhutan, and Nepal will likely experience a rise of 1.5°C to 2.5°C in the moderate scenario put forward by IPCC.[3]

Precipitation

Projecting precipitation changes is especially challenging since the South Asian monsoons exhibit high levels of stochasticity and random variation. In general most models suggest that the wet regions will become wetter and the dry regions drier. Forecasts indicate higher but more variable and intense rainfall in South Asia, except in the relatively drier areas of Afghanistan, western India, and Pakistan, which could see even less rainfall. The monsoon, upon which a vast majority of rural South Asians depend, could become more variable and unreliable, with possible consequences including an increase in the intensity of rainfall and a reduction in the duration of the monsoon (Hu et al. 2000; Lal, Meehl, and Arblaster 2000).

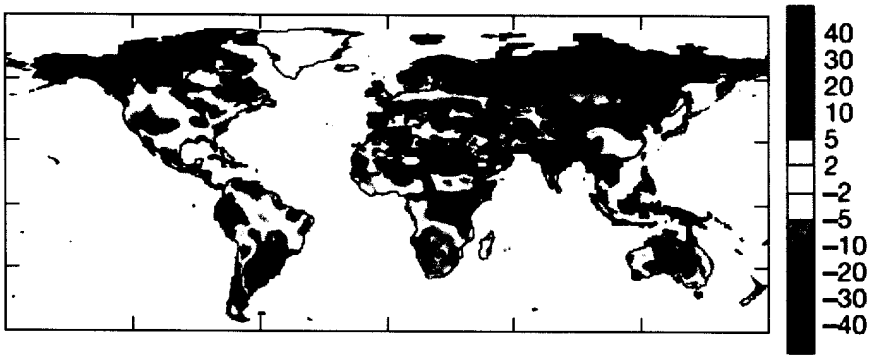
Runoff

Runoff patterns are expected to change significantly in the subcontinent (Figure 2.1), with troubling implications for agriculture. The Indus and Ganges/Brahmaputra basins are expected to experience increased runoff due to precipitation changes and glacial melt (see below). After the glacial melt, however, there would inevitably be significant declines in flows. By 2050, the annual runoff in the Brahmaputra is projected to decline by 14 percent and the Indus by 27 percent (IPCC 2001). Afghanistan is expected to be particularly impacted by a reduction in flows, with considerable impacts on storage and irrigation potential and the reliability of hydropower systems.

[3] The moderate scenario of IPCC assumes low rates of population growth and land use changes; medium availability of resources such as oil and gas; very high gross domestic product (GDP) and energy use growth; and rapid technological change, among other things (Nakicenovic and Swart 2000).

Figure 2.1 Relative Changes in Runoff in the 21st Century

Country	Mean runoff change (%)
Afghanistan	–20 to –10
Bangladesh	20 to 30
Bhutan	10 to 20
India	30 to 40
Maldives	20 to 30
Nepal	10 to 20
Pakistan	> 40



Ensemble (arithmetic) mean of relative change (percentage) in runoff for the period 2041–2060, computed as 100 times the difference between 2041–2060 runoff in the SRES A1B experiments and 1900–1970 runoff in the 20C3M experiments, divided by 1900–1970 runoff.

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(http://www.nature.com/nature/journal/v438/n7066/pdf/nature04312.pdf, accessed November 24, 2008.)

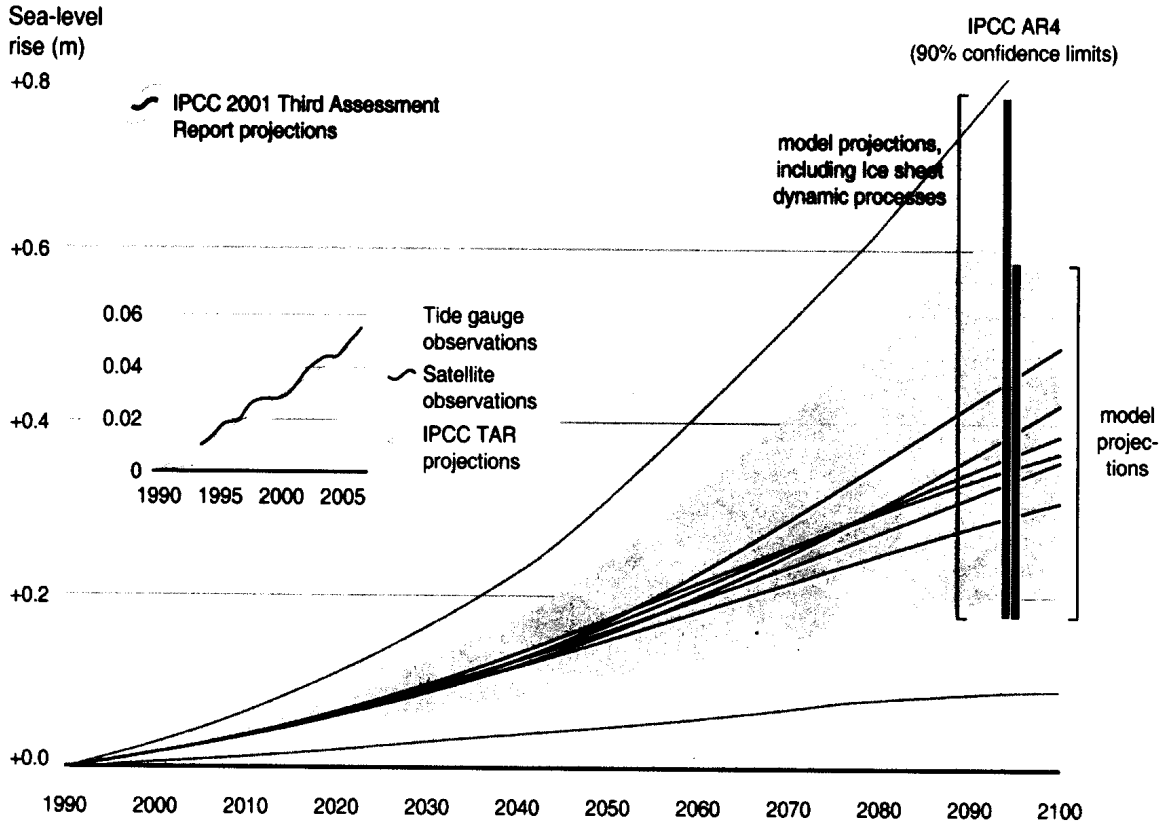
Sea Level Rise

Sea level rise could have a significant impact on low-lying coastal systems and islands. While there are uncertainties as to the extent of change, the IPCC Fourth Assessment (IPCC 2007a) projects a mean 0.4-meter rise by the end of the century (Figure 2.2).[4] In India and Pakistan the current rise in sea level is reported to be about 1 millimeter per year. Sea level rise has both direct inundation impacts and indirect effects, such as changes in salinity levels and increased storm surge effects (IPCC 2007b). The two most vulnerable countries are Bangladesh, with its extensive low-lying deltaic zone (Broadus 1993), and the Maldives, which consists of about 300 islands scattered in the Indian Ocean, most lying below 1 meter above sea level. In the worst

[4] There are numerous other projections of more severe sea level rise that allow for greater melting of the polar ice masses.

case scenarios sea live rise poses an existential threat to the Maldives which is projected to complete submerge.

Figure 2.2 Projected Global Average Sea Level Rise by End of 21st Century



Source: Hugo Ahlenius, UNEP/GRID-Arendal (http://maps.grida.no/go/graphic/projected-sea-level-rise-for-the-21st-century, accessed January 13, 2009).

Climate-Related Disasters

Climate change is likely to increase the intensity and incidence of the many climate-related natural disasters to which South Asia is subject, including tropical cyclones, sandstorms, floods, and droughts. Projections indicate that with warmer surface temperatures the seas will fuel more violent tropical cyclones and winds, increasing the risks to coastal areas (Emanuel 2005).

Glacier Retreat

With rising temperatures the ice mass of the Himalayan Hindu Kush retreated during most of the twentieth century and particularly since 1980. It is estimated that northern Afghanistan experienced a reduction in glacier cover of over fifty percent in the twentieth century alone. In Bhutan (eastern Himalayas), the glacier area cover declined by 8 percent between 1963 and 1993. In Himachal Pradesh, the average rate of glacier melt in the 1999–2004 period was 0.88 meters per year – about twice the rate it was in the 1977–1999 period (World Glacier Monitoring Service 2008). Overall, the melting rate appears to be accelerating in recent years (Meier and Dyurgerov 2002 in Barnett, Adam, and Lettenmaier 2005). The Gangotri glacier (Figure 2.3),

source of the Ganges and one of the largest in the Himalayas, has been receding since 1780 and in recent years the pace of retreat has accelerated.[5] The disruption to this equilibrium is one of the gravest threats facing the region, with increased downstream flooding and the threat of glacial outburst floods in the short term, and potentially catastrophic water shortages in the longer term.

Figure 2.3 Gangotri Glacier, India: Last 200 Years

This composite image from the ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) instrument aboard NASA's Terra satellite shows how the Gangotri Glacier terminus has retracted since 1780.

Source: ASTER image courtesy of NASA, Sept. 9, 2001 (http://www.gsfc.nasa.gov/topstory/2002/20020530glaciers.html, accessed January 13, 2009).

Summary of Climate Risks

The changes to South Asia's climate and their immediate consequences will not impact all countries of the region equally. Table 2.1 provides an approximation and qualitative assessment of the main climate change impacts, though a considerable degree of uncertainty surrounds any projections of regional impact.

[5] During the period 1975 to 1999 the glacier retreated more than 850 meters, with a 76-meter loss from 1996 to 1999 alone.

Table 2.1 Summary of Climate Risks by Country

	Afghanistan	Bangladesh	Bhutan	India	Maldives	Nepal	Pakistan	Sri Lanka
Sea level Rise	–	√	–	√	√	–	√	√
Glacier retreat	√	√	√	√	–	√	√	–
Temperature increase	√	√	√	√	√	√	√	√
Flood frequency	?	√	Likely	√ (some areas)	√	√	√	?
Drought frequency	Likely	√ (some areas)	?	√ (some areas)	–	?	Likely	?

Present: √ Not Present: – Unknown: ?

It is probable that resource-poor communities will suffer the brunt of climate change impacts. The next chapter considers the vulnerability of particular sectors in South Asia to climate change.

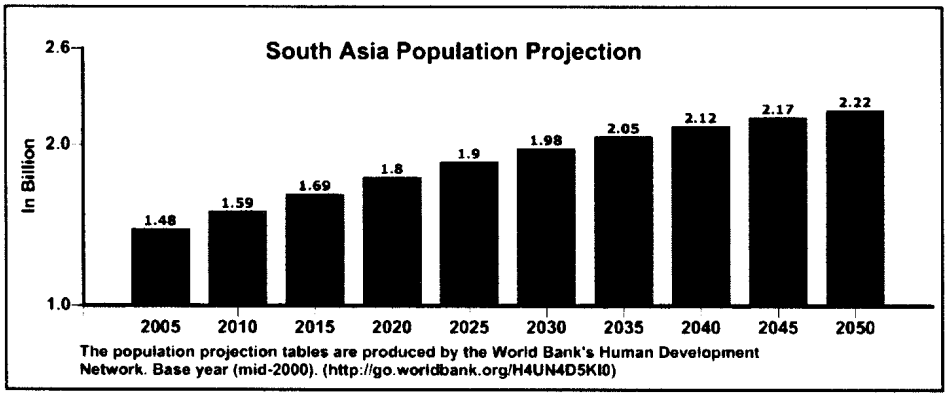
Chapter 3. Vulnerability to Climate Change in South Asia

South Asia faces daunting climate-related development challenges and the impacts of higher temperatures, more variable precipitation, and increased occurrence of extreme weather events are already being felt in the region. Five unique factors make South Asia particularly vulnerable to the impacts of climate change, much more so than the global average. These are discussed in detail next.

Population Increase, Poverty, and Health

First, South Asia has the highest density of poverty in the world. With an estimated 600 million South Asians subsisting on less than US$1.25 a day, even small climate shocks can cause irreversible losses and tip a large number of people into destitution. Much of this impact will be felt in rural areas, which account for about 70 percent of South Asia's population and 75 percent of the poor. By 2050 South Asia's population is projected to rise from the current 1.5 billion to 2.2 billion. Much of the population growth is projected to emerge in rainfall-dependent rural areas placing huge demands on the already stressed and degraded natural resource base (Figure 3.1).

Figure 3.1 South Asia Population Projections



Source: Human Development Network, World Bank.

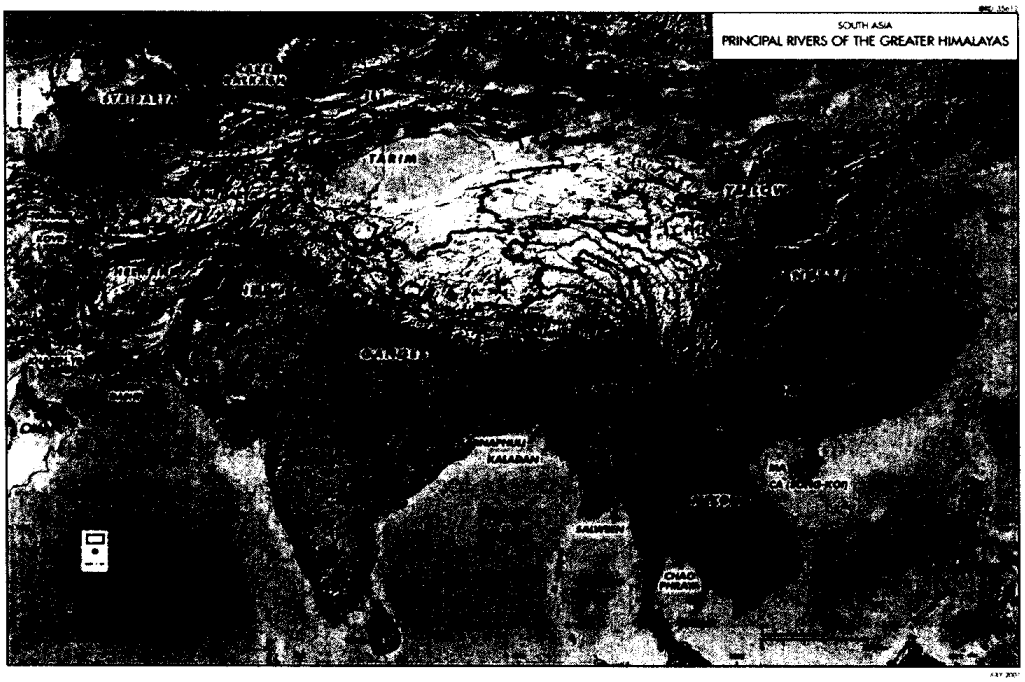
A number of groups are likely to be particularly vulnerable to the impacts of climate change. These include women in poor rural communities, whose workload will increase as crop yields fall and water becomes scarcer; pastoralists in semi-arid areas, already living on the margins of habitable land; indigenous people who depend on threatened forest resources; and coastal communities, such as those of the Sundarbans, whose lands could be inundated by sea level rise.

Threats to Water Supply and Agriculture

Second, South Asia is endowed with great rivers, which are the lifelines of the regional economy. The ice mass covering the Himalayan-Hindu Kush mountain range is the source of the nine largest rivers of Asia (Figure 3.2), including the Ganges, Brahmaputra, and Indus. Glacial melt coupled with more variable precipitation could severely compromise livelihoods and the

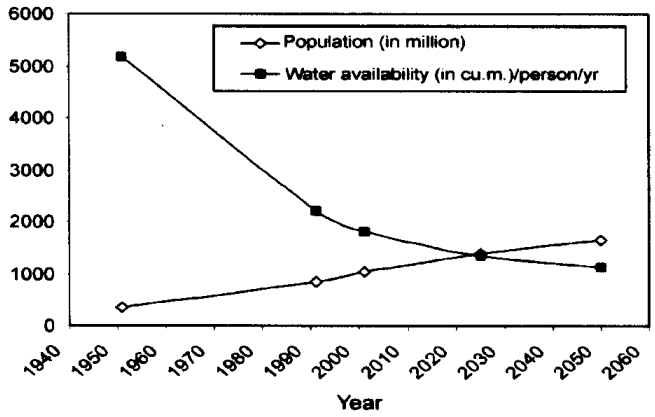
future prospects of agriculture. The decline in per capita water availability (Figure 3.3) is projected to continue.

Figure 3.2 Principal Rivers of the Himalayas



Source: World Bank 2007. IBRD 35612.

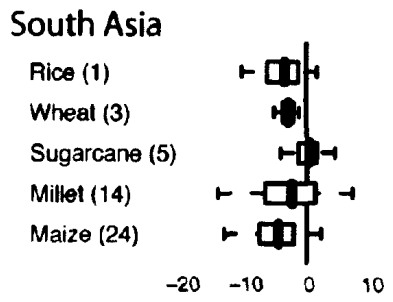
Figure 3.3 Observed and Projected Decline in Annual Average Per Capita Water Availability in India



Source: Mall et al. 2006.

Climate change poses a particular challenge to the agricultural sector, with effects that are difficult to predict. Some increase in yields may result from higher levels of CO_2 in the atmosphere ("carbon fertilization"), but this will be limited to certain geographical areas and species. The negative impact of increased temperatures and evapotranspiration on crop yields will be most keenly felt in already heat-stressed arid and semi-arid areas. Taken overall, most major food crops in South Asia are projected to experience a decline in yields (Box 3.1).

Box 3.1 Climate Change Impacts on Yields of Major South Asian Crops



The accompanying figure shows the estimated impacts, by 2030, of climate change on yields of five major crops in the South Asia region, as a percentage change compared to current yields (Lobell et al. 2008). For each crop, the dark vertical line represents the middle value out of 100 different model projections (range shown in yellow). The number in parentheses is an overall global ranking given to each crop based on its importance to food security.

Reproduced/modified with permission from Lobell et al. 2008.

"Climate-proofing" water-dependent livelihoods is critical to maintaining and expanding South Asia's growth. As many of the rivers in the region are shared transboundary systems, regional coordination and cooperation will be vital in dealing with such issues as river basin management and governance, investment in infrastructure, and widening the knowledge base on the impacts of climate change on the region's water systems.

Urbanization

Historically, urbanization has proceeded relatively slowly in South Asia, but this trend is changing drastically throughout the region (Table 3.1). Projections indicate that by 2050 about half the region's population will dwell in cities. Given current trends, South Asia will host five of the world's eleven megacities – Mumbai, Delhi, Dhaka, Karachi, and Kolkata. The cities of South Asia already face immense challenges, including low-quality building stock, poorly maintained infrastructure, unplanned growth, inadequate service delivery, scant livelihood opportunities, and susceptibility of the poor populations to ill-health. Climate change will add to these pressures as temperatures rise, water and energy supplies are stretched, sea levels creep up, extreme weather events become more frequent (especially affecting coastal cities), and rural–urban migration increases as agricultural yields are hit by changes in climate, creating "climate refugees" (St. Louis and Hess 2008).

Table 3.1 Percentage of Total Population in Urban Areas

	1990	2006
Afghanistan	18.3	23.3
Bangladesh	19.8	25.5
Bhutan	7.2	11.4
India	25.5	29.0
Maldives	25.8	30.1
Nepal	8.9	16.2
Pakistan	30.6	35.2
Sri Lanka	17.2	15.1

Source: UNESCAP 2007.

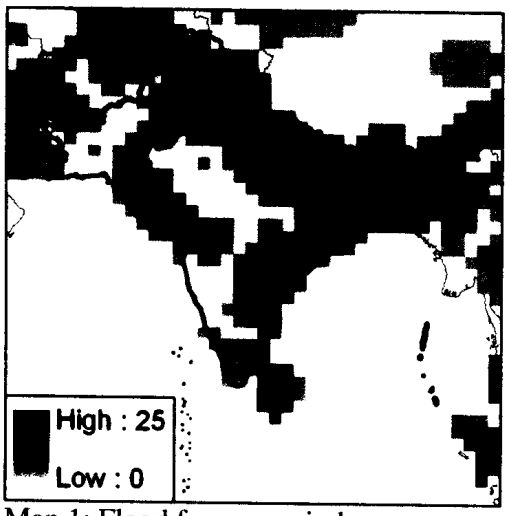
Building urban resilience requires improvements in infrastructure and governance and increased finance. Considerable opportunities exist to reap co-benefits in attending to the climate change and development needs of cities. Improving the efficiency of water supply production and distribution, for example, can help curb greenhouse gas emissions and preserve water availability, while providing better services for the urban poor (World Bank 2008a).

Vulnerability to Natural Disasters

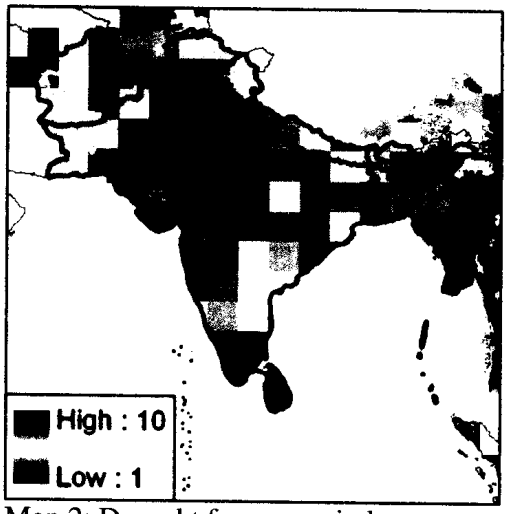
South Asia suffers an exceptionally high number of natural disasters. Between 1990 and 2008, over 750 million people – 50 percent of the population in the region – were affected by a natural disaster, leaving almost 60,000 dead and about US$45 billion in damages. Figure 3.4 shows the principal hazard risks in the region, including flood, drought, landslides, and tropical storms, and the distribution of the "hotspots" where they are most likely to be encountered.

Economic losses and loss of life from natural disasters place a heavy and increasing burden on public expenditures that is unlikely to be sustainable in the future. As climate-related risks intensify there will be a need to respond proactively to build resilience through prevention and preparedness rather than through relief and response. Enhancing the ability of local communities to manage current natural hazard risks will help improve their capacity to prepare for and respond to future climatic changes.

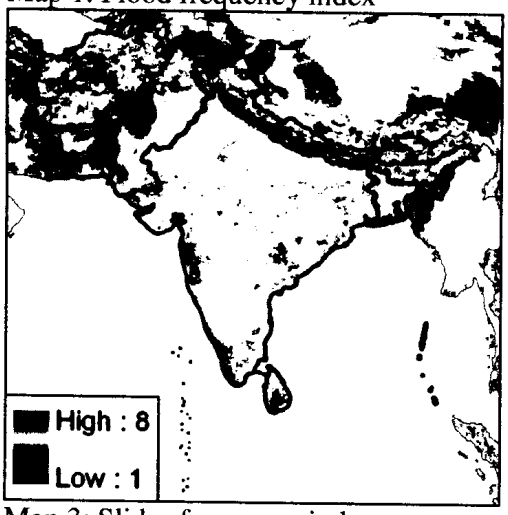
Figure 3.4 Distribution of Hazard Risk Hotspots in South Asia



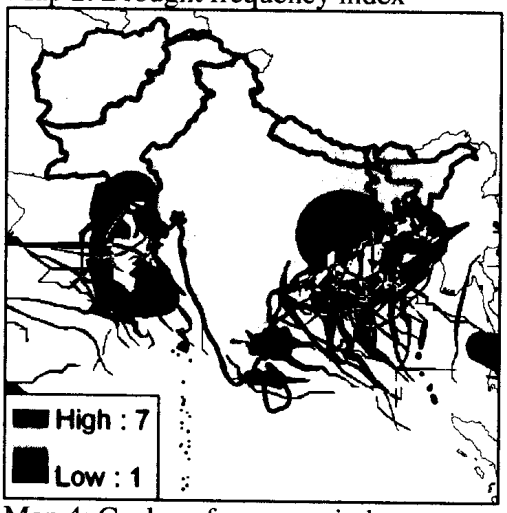
Map 1: Flood frequency index



Map 2: Drought frequency index



Map 3: Slides frequency index



Map 4: Cyclone frequency index

Note: Maps 1–4 display the South Asia region with hazards data derived from a global source.

Source: Reproduced/modified from Dilley et al. 2005.

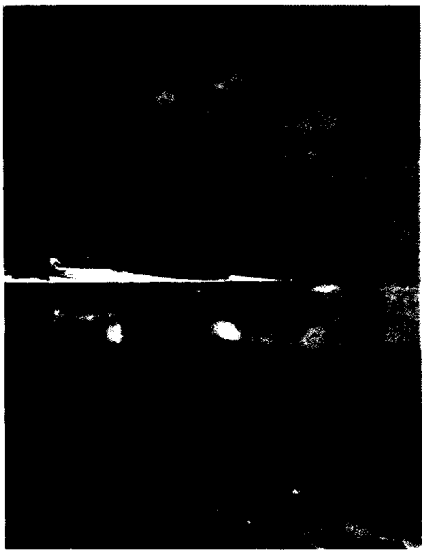
Sensitivity of Ecosystems

Finally, South Asia is endowed with an exceptional array of biodiversity across a broad range of ecosystems and habitats. This rich ecological landscape has been integral to the well-being and livelihoods of millions of people, supplying food, water, fodder, fuelwood, clothing, shelter, and medicine, and supporting life through nutrient cycling, habitat growth, primary production, oxygen generation, and water purification. Ecosystems also play a crucial role in absorbing greenhouse gas emissions.

The natural resources of the region are facing tremendous pressure as economic expansion and a burgeoning population lead to unsustainable resource extraction and accelerating levels of air and water pollution. Climate change will contribute to these stresses throughout the whole range of ecosystems, as summarized in Table 3.2. Biodiversity and ecosystem services will be severely threatened as vegetation boundaries shift in response to changing temperature and precipitation patterns. This effect will be particularly marked in the Himalayan range, where vegetation types

are expected to migrate upwards in response to global warming (CBD 2003; IPCC 2007c). Other significant impacts of climate change predicted for the South Asia region (and already starting to occur) include loss of savanna cover, desert expansion, and coral reef destruction (Box 3.2). There are compelling ethical and economic reasons to be concerned about these impacts. The region's dwindling habitats host numerous endangered and often endemic species. Simultaneously these regions provide vital life sustaining environmental services (such as watershed benefits).

Box 3.2 Threat of Climate Change to Coral Reef Formation



Even an ocean warming of 1°C to 2°C will cause bleaching of coral reefs, which occurs when the symbiotic algae in coral tissues separate from their hosts due to sustained stress, weakening the health and services of corals and dependent species and distorting the dynamics within the ecosystem (UNEP 2008). Sustained ocean warming of 3°C to 4°C would cause large-scale coral mortality.

Ocean acidification, another consequence of climate change, will slow coral reef formation, making the reef more susceptible to human and natural pressures and leading to severe degradation of reefs as the rate of erosion exceeds the rate of calcification (CBD 2003; UNEP 2008), reducing the ability of the reef to prevent coastal erosion and flooding.

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The effects of climate change upon ecosystems and biodiversity are hugely complex and largely unknown. Knowledge building should respect and accommodate the valuable store of local knowledge of ecosystem services and their management.

Table 3.2 Climate Change Impacts and Vulnerability Index

Ecosystems	Threats	Afghanistan	Bangladesh	Bhutan	India	Maldives	Nepal	Pakistan	Sri Lanka
Coastal (mangroves, mudflats, estuaries)	Inundation, salination, storms, species loss								
Coral reefs	Bleaching, acidification, loss of ecological and protective services, reduction in species diversity								
Inland wetlands	Desiccation, drainage and diversion, degradation and service loss								
Forests	Loss of forest cover and species, altered composition and structure, increased evapotranspiration								
Mountain (subtemperate, temperate)	Altitudinal shifts in vegetation disrupting species types								
Mountain (subalpine, alpine)	Loss of vegetation cover								
Glaciers	Loss of coverage								
Desert	Expansion								
Rangelands & grasslands	Regime shift, degradation due to overgrazing and increased incidence of fire								
Freshwater (rivers, lakes)	Desiccation, increased salinity at coast, degradation due to increased demand								
Species diversity (floral & faunal)	Loss of diversity and habitat, changes in species composition and food web								

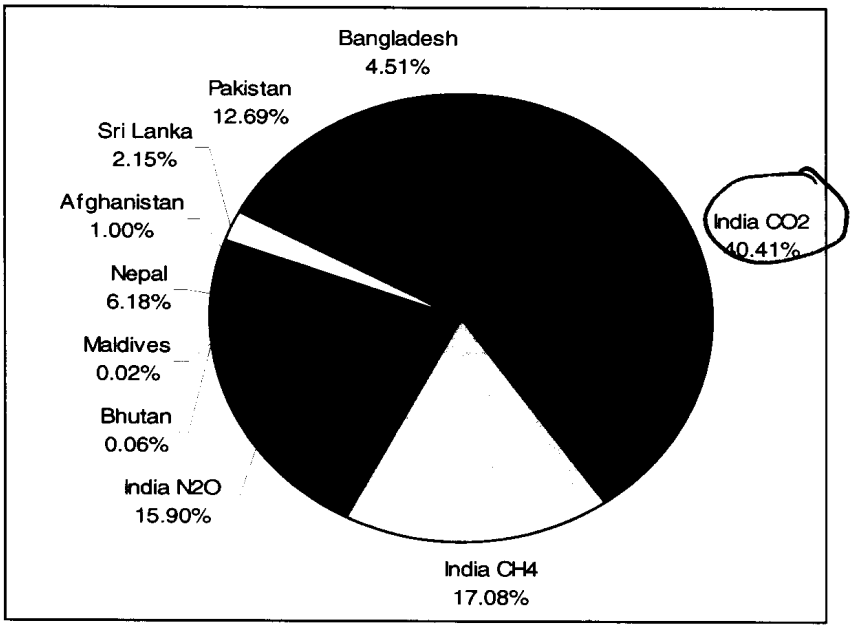
Key: Locations particularly vulnerable to impacts of climate change.

Chapter 4. South Asia's Contribution to Greenhouse Gas Emissions

While vulnerability to climate change is high in South Asia, the region has also emerged as a visible contributor to the greenhouse gas emissions that are triggering climate change. Higher emissions are driven by urbanization, industrialization, and prosperity, all of which are part of a broader process of development that has fueled growth and lifted millions out of poverty. The main sources of emissions in South Asia are from energy production, transformation, and consumption, combined with land use change and agriculture. Projections also suggest that transport-related emissions could escalate in the near future.

Greenhouse gas emissions in South Asia have risen by about 3.3 percent annually since 1990, more rapidly than in any other region except the Middle East. India, the economic powerhouse of South Asia, is predictably the largest source of regional emissions (Figure 4.1), though per capita emissions are still low compared to other regions (Figure 4.2).

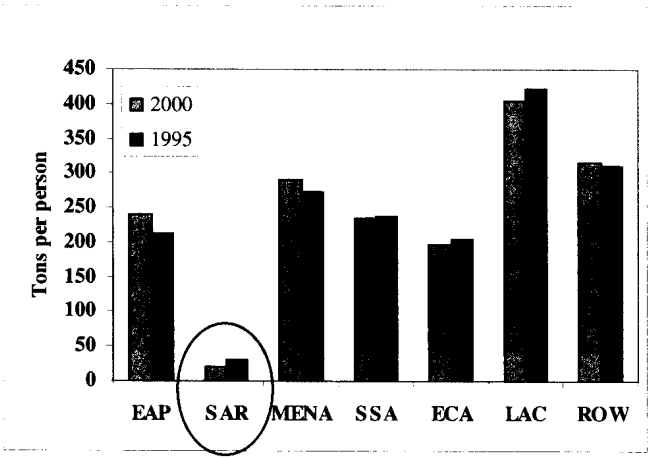
Figure 4.1 Greenhouse Gas Contributions by Country in South Asia, 2000



Note: Figure only provides contribution by gas for India in CO_2 equivalents.

Source: Climate Analysis Indicators Tool (CAIT) Version 6.0 (Washington, DC: World Resources Institute, 2009) (http://cait.wri.org/cait.php, accessed March 8, 2009).

Figure 4.2 Per Capita Greenhouse Gas Emissions by Region, 1995 and 2000

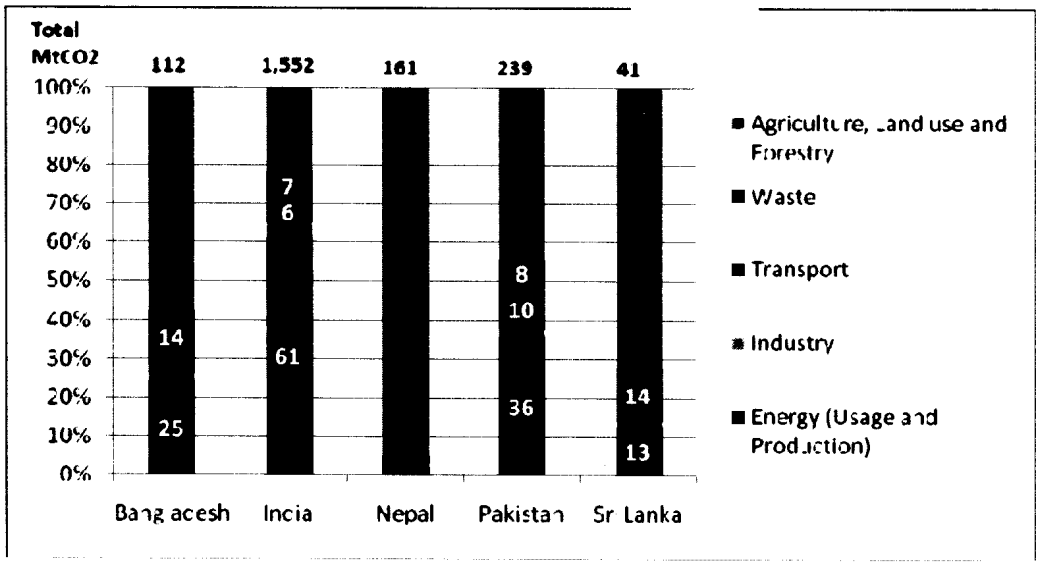


Key to abbreviations: EAP, East Asia and Pacific; SAR, South Asia Region; MENA, Middle East and North Africa; SSA, sub-Saharan Africa; ECA, Europe and Central Asia; LAC, Latin America and the Caribbean; ROW, Rest of the World.

Source: Climate Analysis Indicators Tool (CAIT) Version 6.0 (Washington, DC: World Resources Institute, 2009) (http://cait.wri.org/cait.php, accessed March 8, 2009).

The sources of emissions vary substantially across the region (see Figure 4.3). In India, energy-related consumption and transformation accounts for the bulk of emissions, reflecting the economy's rapid industrialization. At the other end of the spectrum lie Nepal and Sri Lanka where changes in land use (deforestation) and agriculture are the main sources of emissions (Figure 4.3). Transport-related emissions across the region are typically low, but could rise rapidly with greater prosperity and sustained economic growth. These three sources of emissions are considered briefly in this chapter.

Figure 4.3 Greenhouse Gas Emissions by Sector, 2000 (% of total and total $MtCO_2$)



Source: Data from Climate Analysis Indicators Tool (CAIT) Version 6.0 (Washington, DC: World Resources Institute, 2009) (http://cait.wri.org/cait.php, accessed March 8, 2009).

Energy Sector

Buoyant economic growth in the past decade has fueled an insatiable thirst for energy in South Asia. Coal is the backbone of the energy sector and is expected to remain the dominant fuel that

will power the economies of South Asia, while contributing significantly to the region's greenhouse gas emissions. Industry is another major contributor: much of the industrial output is from a vast diversity of small- and medium-scale enterprises that utilize outdated and inefficient technologies and processes.

India exemplifies the problems facing the area. Coal is abundant and relatively cheap. It seems destined to remain the primary source of energy for India, which has about 38,000 million tons of oil equivalent of proven coal reserves, the third largest in the world after the United States and China. Coal-based electricity currently accounts for 70–80 percent of the country's power generation, and around 30 percent of its greenhouse gas emissions. Strategies to lower emissions by diversifying into cleaner sources of power are constrained by the country's lack of reserves of cleaner fuels, such as oil, gas, and uranium. Hydropower potential is significant and large in absolute terms (150,000 megawatts), but small compared to the country's vast energy needs, and social and environmental concerns often limit exploitation.

Bangladesh, Pakistan, and Sri Lanka will also increasingly see coal emerge as the leading fuel for incremental generation of power. Bangladesh and Pakistan have substantial unexploited coal reserves, and Sri Lanka can import coal at competitive prices. More active interventions are needed to tilt the balance in favor of cleaner technologies. For Pakistan, the alternative to coal is likely to be natural gas imported from its oil-rich neighbors in the Middle East and Central Asia. For Sri Lanka, the alternative source of supply would be imported liquefied natural gas, though plans for a massive expansion of coal-fired energy are well advanced. Bangladesh has significant reserves of natural gas, but exploration drilling has not kept pace with demand, and would benefit from greater policy support.

On the positive side, there are considerable opportunities in all sectors for energy efficiency gains and loss reduction in South Asia (Table 4.1). Such actions would have the dual benefit of increasing the cost-effectiveness of economic activity while reducing greenhouse gas emissions.

Table 4.1 Energy Efficiency Opportunities and Measures in Key Consuming Sectors

Sector	Energy efficiency improvement opportunities
Buildings	Integrated building design and measures such as better insulation, advanced windows, energy-efficient lighting, space conditioning, water heating and refrigeration technologies
Industry	Industrial processes, cogeneration, waste heat recovery, preheating, efficient drives (motor pump, compressors)
Cities and municipalities	District heating systems, combined heat and power, efficient street lighting, efficient water supply, pumping, and sewage removal systems
Agriculture	Efficient irrigation pumping and water use, such as drip irrigation
Power supply	*New thermal power plants:* Combined cycle, supercritical boilers, integrated gasification combined cycle, etc. *Existing generation facilities:* Refurbishment and repowering (including hydro), improved operation and maintenance practices, and better resource utilization (higher plant load factors and availability) *Reduced transmission and distribution losses:* High-voltage lines, better insulated conductors, capacitors, efficient and low-loss transformers, and improved metering systems and instrumentation *Intensified investigation of renewable options:* Solar and wind power, hydro-electricity (including possibility of increased regional trade)
Transport	Efficient gasoline/diesel engines, urban mass transport systems, modal shifts to inter- and intra-city rail and water transport, improved fleet usage, compressed natural gas (CNG) vehicles
Households	Efficient lighting, appliance efficiency, improved cook stoves

Agriculture and Deforestation

In the rural sector crops, livestock related emissions and deforestation are the main contributors of greenhouse gases. In India for instance, with almost 300 million cattle, the contribution of livestock to emissions is estimated at approximately 13 percent of the total. Flood irrigated rice is another major source of emissions in the region. Through much of South Asia the forest cover has largely stabilized. The exceptions are Nepal and Sri Lanka where the bulk of emissions are driven by deforestation. Agriculture has much untapped potential to reduce emissions through changes in agricultural practices and by reducing forest loss. The most promising areas appear to be innovations in dry rice cultivars and planting techniques that simultaneously promote irrigation efficiency and higher productivity. Improving the diet of livestock can also reduce methane emissions, though this is especially challenging in South Asia where much of the herd subsists on common pastures with little supplementary feeding.

Transport Sector

South Asia's emissions from transport are currently low compared to the world average (Table 4.2). India's rate of car ownership in 2000 was just 10 vehicles per 1,000 persons, compared to a world average of about 113 vehicles per 1,000 persons (Muralikrishna 2007). However, this situation is likely to change radically in the near future, with more rapid urbanization, rising household incomes, and the availability of cheaper vehicles leading to an escalation of transport demand. In India alone the total vehicle stock increased fourfold from 19 million in 1990 to 73 million in 2004, and car sales are projected to increase by 10 percent per annum for the next two decades, significantly raising the trajectory of future CO_2 emissions (Bose and Spurling 2005).

There are policy and technology choices that could lower the emissions growth rate while increasing mobility, improving air quality, reducing traffic congestion, and lowering transport and energy costs. Adoption of fuel economy and CO_2 emissions standards for new vehicles, and improved maintenance of the existing fleet, would increase fuel efficiency and reduce greenhouse gas emissions.

Table 4.2 Per Capita and Per Unit of GDP Transport CO_2 Emissions by Region and by South Asian Country, 2005

Region/Country	Per capita CO_2 emissions (kilograms of CO_2)	CO_2 emissions per US$ of GDP[a] (grams of CO_2)
World	985	116
South Asia	94	33
Bangladesh	*31*	*17*
India	*89*	*29*
Nepal	*31*	*22*
Pakistan	*170*	*81*
Sri Lanka	*279*	*68*

a. In 2000 US dollars.

Source: Calculations by Gorham (2008) based on data from the International Energy Agency.

Utilization of biofuels, particularly ethanol and biodiesel, holds promise for reducing the life-cycle carbon content of fuels. The government of India, for example, has pursued since 2003 an ambitious National Biodiesel Mission with the objective of supplying 20 percent of national diesel demand with domestically produced biodiesel, primarily from *Jatropha*, a desert-blooming plant that does not compete with food products and can be cultivated on marginal land (Gonsalves 2006; Kukrika 2008). The challenge is to ensure that biofuels do not compete with food production or encroach into the forest frontier.

Policy approaches that promote integrated public transport systems within the wider context of urban planning have exhibited potential. India, for example, has undertaken substantial steps to respond to the transport demands of urbanization through technological transformation of vehicle fleets in many of its cities, adoption of the National Urban Transport Strategy, propagation of a funding mechanism for urban renewal, and preparation of a nationwide demonstration Sustainable Urban Transport Project (supported by the Global Environment Facility).

Chapter 5. Conclusion: Strategic Approaches to Climate Change in South Asia

South Asia faces a significant challenge in continuing to develop while grappling with the consequences of climate change. Responses to climate change can be broadly grouped into low-carbon growth policies and adaptation measures, though there is obviously considerable overlap between the two. Adaptation is necessary to limit the damage caused by climate change. It enables communities to preempt and manage climate risks and governments to protect and "climate-proof" high-value assets and infrastructure. Low-carbon growth approaches (often said to involve "mitigation") are also vital, since no amount of adaptation can protect South Asia from the potentially catastrophic effects of climate change.

Recognizing that industrialized countries have contributed most to the existing stock of emissions, there is broad consensus that developed countries would need to take the lead and shoulder the financial burden for low-carbon growth strategies in the near term. However, there remain wide opportunities for developing countries to participate in emission stabilization in ways that support their development objectives. Nevertheless, the resources needed to tackle the problem vastly exceed available funds. Cost estimates point to a deficit in the order of hundreds of billions of US dollars per annum for several decades (World Bank 2008b). Though limited, a number of funding opportunities do exist for financing both low-carbon growth strategies and adaptation to the impacts of climate change.

Adaptation: Building Resilience to Future Climate Change Shocks

The most promising approaches will not only assist in building resilience to the impacts of climate change but will also be of benefit in reducing emissions of greenhouse gases.

√ **Invest in knowledge.** There is considerable uncertainty regarding the timing, location, and severity of future climate change impacts. Increased understanding of the nature and magnitude of the threats associated with climate change will help build institutional capacity to respond through appropriate policy development and implementation.

√ **Develop cross-sectoral response mechanisms.** While several climate change risks are intensifications of existing problems – more severe floods, more frequent droughts – others are new and unprecedented, such as glacial melt and sea level rise, and will affect all sectors of the economy. Institutions will be severely challenged to respond to these risks and cross-sectoral approaches will be required in recognition of the broad scale of the problems faced.

√ **Focus on the poor.** The poor have limited resources and are often employed in sectors such as agriculture that are exposed to high climate risks. Building the climate resilience of these groups must remain a priority and would also generate immediate development dividends.

√ **Promote regional cooperation to address common threats.** The most severe threats, for example glacier retreat and sea level rise, transcend national boundaries, requiring regionally coordinated solutions. Finding effective solutions for flood control, irrigation, and river transport will require cooperation between upper and lower riparian countries. Also, regional cooperation in energy trade can assist in lowering emissions.

√ **Maintain the integrity of environmental services.** Climate change is a consequence of damaged and diminished ecoservices, requiring remedial measures to protect and restore

ecosystem integrity, which is also a cost-effective way of building climate resilience and providing a buffer against climate impacts.

The Global Environmental Facility (GEF) has been the main source of grant and concessional funding for adaptation projects, including vulnerability and adaptation assessments and capacity-building projects. The Global Facility for Disaster Risk Reduction (GFDRR) is an additional instrument that can finance development projects and programs that enhance local capacities for disaster prevention and emergency preparedness and adaptation to climate change. Activities supported by GFDRR in South Asia amount to US$4.3 million. More recently the Climate Investment Funds (CIF) have emerged as a major effort for financing both adaptation and low-carbon growth. Approximately US$600 million has been allocated to adaptation programs through the Pilot Program on Climate Resilience subfund. Table 5.1 summarizes the main funding sources and their targeted areas of action. South Asia's share in these resources has until now been limited.

Table 5.1 Sources of Funds for Adaptation

Fund	Funding source	Total funds mobilized	Operational criteria	Main activities of support
Global Environment Facility (GEF) Trust Fund	GEF		Incremental cost to achieve global environmental benefits	Vulnerability and adaptation assessments as part of national communications and enabling activities
Strategic Priority on Adaptation (SPA)	GEF	US$50 million	Incremental cost guidance with some flexibility, especially for Small Grants Programme	Pilot and demonstration projects on adaptation Small Grants Programme (US$5 million) to support community-based adaptation
Special Climate Change Fund	Voluntary contributions from 11 developed countries	US$45.4 million	Additional cost of adaptation measures Sliding scale for co-financing	Addresses adaptation as one of the four funding priorities
Least Developed Countries Fund	Voluntary contributions from 13 developed countries	US$75.7 million	Guiding principles: country-driven approach, equitable access by least developed countries, expedited support and prioritization of activities Provision of full cost funding for adaptation increment	Implementation of national adaptation programs of action (NAPAs)
Adaptation Fund	2 percent share of proceeds from Clean Development Mechanism (CDM)	Under negotiation	Guiding principles: country-driven and a learning-by-doing approach, sound financial management and transparency, separation from other funding sources	Concrete adaptation projects and programs identified in decision 5/CP.7 of the United Nations Framework Convention on Climate Change (UNFCCC)
Pilot Program for Climate Resilience	Voluntary contributions	US$600 million	Guiding principles: country-driven catalytic programs to build climate resilience	Pilot projects on adaptation that leverage other resources

Pursuit of Low-Carbon Growth Strategies

Urgent global action is needed to control and reduce emissions, as delayed or limited emission stabilization will necessitate considerably greater investment in risk management and climate change adaptation. With a large proportion of South Asia's population below the poverty line, any low-carbon growth strategy must be consistent with the region's development objectives of improving living standards and incomes.

√ **Generate co-benefits.** The most productive policies will be those that have global benefits in reducing greenhouse gases, while generating considerable domestic benefits in the form of reduced foreign energy dependence, greater energy efficiency and security, improved natural resource management, better air quality, and improved rural welfare. Many of the measures that help reduce greenhouse gas emissions contribute significantly to sustainable development.

√ **Promote wider adoption of clean technologies.** Development, deployment, and diffusion of affordable technology are critical to enabling developing countries to meet the challenges of climate change. New technologies are expensive and risky, but with further research and adoption, encouraged by demand and supply incentives, they can become more economical and accessible. Developed countries have an important role to play in facilitating the diffusion of clean technologies by lowering barriers to adoption.

√ **Make full use of financing opportunities.** The UNFCCC principle of "common but differentiated responsibility" recognizes that current climate risks are the consequence of past actions by developed countries, and that there is a need for assuring equal and fair access to the global atmospheric commons and funding for mitigation efforts in developing countries. There is considerable potential for South Asia to take greater advantage of carbon finance instruments and other special financial vehicles established by bilateral donors, such as climate change trust funds, and any international financing mechanism to be agreed under the second commitment period of the Kyoto Protocol (post-2012).

Financing the Transition to Low-Carbon Economies

The expansion of the carbon market in recent years has promoted the implementation of climate-friendly technologies in numerous developing countries and transition economies. The volume of carbon emission reduction reached 2.98 billion tons of CO_2 equivalent in 2007, amounting to trades of US$64 billion. Several mechanisms exist to promote emission reductions. The Clean Technology Fund (a component of the new Climate Investment Funds) promotes low-carbon technologies that could have transformational and multiplier impacts in reducing greenhouse gas emissions.

Table 5.2 summarizes the available funds for low-carbon financing in the South Asia region.

Table 5.2 Low-Carbon Growth Financing – Current and Past Funds[6]

Carbon finance fund	Description	Funds (US$ million)
Prototype Carbon Fund	Pioneers the market for project-based greenhouse gas emission reductions while promoting sustainable development and offering a learning-by-doing opportunity to its stakeholders	180
Bio-Carbon Fund	Funds projects that sequester or conserve carbon in forest and agro-ecosystems. The fund aims to deliver cost-effective emission reductions, while promoting biodiversity conservation and poverty alleviation.	53.8
Community Development Carbon Fund	A public/private initiative designed in cooperation with the International Emission Trading Association and UNFCCC that supports projects that combine community development attributes with emission reductions to create development plus carbon credits and improve the lives of the poor and the local environment.	128.6
Italian Carbon Fund	A fund that purchases greenhouse gas emission reductions from projects in developing countries and countries with economies in transition that may be recognized under CDM and Joint Implementation. It is open for Italian private and public sector entities.	155.6
Danish Carbon Fund	The fund supports low-carbon growth initiatives by Danish public and private entities in wind, combined heat and power, hydropower, biomass use for energy, and landfill.	68.5
Spanish Carbon Fund	Purchases greenhouse gas emission reductions from projects under the Kyoto Protocol to assist low-carbon growth approaches to climate change while promoting the use of cleaner technologies and sustainable development in developing countries and economies in transition.	278.6
Umbrella Carbon Facility	A facility that pools funds from existing International Bank for Reconstruction and Development-managed carbon funds and other participants for the purchase of emission reductions from large projects.	719
Forest Carbon Facility	Assists developing countries in their efforts to reduce emissions from deforestation and degradation by providing value to standing forests.	300
Carbon Partnership Facility	The facility is designed to develop emission reductions and support their purchase over long periods after 2012. This facility is prepared for large-scale, potentially risky investments with long lead times, which require durable partnerships between buyers and sellers.	
Clean Technology Fund	Designed to promote transformational investments in low-carbon technologies.	5,000

[6] Amounts available may vary from those shown depending upon disbursements, and contingencies of the various funds.

In sum, the current framework for climate change financing is provisional and the funds available are not commensurate with country needs for either adaptation or emission stabilization. The financial instruments to address the climate change challenge in developing countries are still evolving. There is a need for considerably greater international commitment, cooperation, and coordination on funding if the world is to successfully address the development challenges brought about by climate change.

Table 5.3 Climate Change in South Asia: Summary of Sectoral Risks and Priority Responses

Sector	Risks	Priority responses	World Bank's potential role
Regional and Cross-sectoral	Information gaps Limited coordination between sectors and countries Funding gaps for both adaptation and low-carbon growth	Knowledge products Institutional coordination and strengthening Resource mobilization	Climate policy support targeted to needs Low-carbon growth studies (India, Pakistan, Sri Lanka) Trade barriers to clean technology adoption Poverty-climate linkages Build knowledge partnerships between countries and sectors Assist with resource mobilization
Agriculture	Declining yields of major crops Agriculture becomes unviable in marginal areas, e.g.: arid, semi-arid, coastal areas (saline intrusion affects these zones due to sea level rise) Crop destruction by extreme events	Promotion of climate-resilient cropping patterns and techniques Agricultural research and extension for promoting climate-resilient crop varieties Improvements in risk management (e.g. climate insurance and contingent credit schemes) Irrigation development and increased investment in water harvesting infrastructure at required scales that take account of climate risks	Technical assistance (TA) to help in dissemination of climate-resilient crop varieties and cropping systems Investments in agriculture research, improved extension services, irrigation and livelihood diversification Sector work to identify innovative financing mechanisms (e.g. climate insurance, carbon credits)
Water	Glacier melting in the Himalayas, including lake outburst Floods Droughts Saline intrusion in coastal aquifers (due to sea level rise)	Regional cooperation on international rivers and river basins Improved water resources management Climate-sensitive infrastructure packages to build climate resilience Knowledge investments, e.g. to assess risks in Himalayas and the region's large river basins Increased research on new water-efficient technologies and (drought-resistant) crop varieties	Convening power/leadership role to catalyze regional cooperation Honest broker role without footprint Technical assistance Lending and financing for hydropower and storage

Energy	Political economy (non-climate) barriers to developing regional energy trade Poor-quality local coal Ageing and inefficient thermal power generation High transmission and distribution losses Inefficient energy use Poor energy pricing frameworks	Regional energy trade from power surplus countries (Bhutan, Nepal for hydro and Sri Lanka for wind) to energy-deficient economies (India and Pakistan) Cleaner coal through rehabilitation and replacement of inefficient generation units Harness hydropower potential Energy efficiency and reduction of system losses Investment in (non-polluting) renewable energy	Scale-up transmission &distribution (T&D) loss reduction investments in India, Pakistan and Bangladesh, including selected Indian state-level T&D companies Expand renewable energy support through leveraging climate investment funds and advancing investments in hydropower (India, Nepal, Pakistan), coal (India), gas-fired (Bangladesh) Operationalize energy efficiency possibilities in India, Pakistan and Bangladesh Low-carbon growth studies for Pakistan, Bangladesh, and Sri Lanka Advance energy pricing reform dialogue Groundwork and dialog for investments in regional energy trade infrastructure
Natural Disasters	Higher probability of extreme climate events (cyclones, storms, floods, heat waves) Higher probability of slow onset disasters (prolonged droughts, sea level rise)	Emergency preparedness and information (early warning systems) Risk mitigation: structural and non-structural measures Catastrophe risk financing or transfers (where needed)	Strengthening institutional capacity for disaster reduction management and emergency response Technical assistance Funding support for disaster preparedness and adaptation Donor mobilization

Transport	Increase in number of private vehicles and usage per vehicle Increase in age and inefficiency of vehicle fleet Ongoing deterioration of public transport in cities Expansion of low-density urban land development that is not friendly to public transport and non-motorized transport	Sustainable and energy-efficient public transport and aggressive transport demand management, particularly in megacities Reorient urban growth patterns and practices to create networks of walkable neighborhoods, particularly in high-growth, medium-sized cities Fuel efficiency standards for road vehicles	Financial and technical support for the - development of more energy-efficient transport modes, such as public transport, non-motorized transport and clean transport - transitioning traffic management priorities from private transport to public transport and non-motorized transport - long-term land use and transport planning Greater weight given to assessment of transport impacts (particularly on energy use and climate change) in the project appraisal process Institutional support to: - Capacity development for transport planning, operation and management at national and local level - Regional or national initiatives that help develop and disseminate information on fuel efficiency standards and best practices in vehicle maintenance - National or local initiatives that advance the adoption of transport CO_2 emission targets and monitoring mechanisms
Social	Increased poverty, vulnerability, and nutrition insecurity Social conflict Aggravation of social exclusion and inequity Indebtedness in climate-vulnerable areas Migration Increased urban slum population	Awareness raising, social mobilization, and capacity building Education and skill training for women and other vulnerable groups for reducing agricultural dependence Promotion of self-help groups, enhancing access to microfinance and banking services Strengthening public-private partnership and social capital of vulnerable groups through improved access and involvement in decision making Promotion of community-based asset building and sharing of natural resources	Financial and technical support for promoting equity, inclusion, rights and livelihoods through targeting vulnerable groups and enhancing voice, decision making and capacity of the vulnerable to adapt Partnership with community-based organizations (CBOs), coastal state organizations (CSOs), non-governmental organizations (NGOs) and private sector for capacity building. Governance, strengthening institutions and social capital by initiating parallel capacity building and social accountability initiatives

Health	Increased incidence of water-related diseases (malaria) Heatstroke Direct health risks; e.g. injury and death caused by extreme events	Awareness of the health implications of climate change Monitoring and surveillance of disease and improved health sector response and training for new disease risk profiles Improved water supply and sanitation	Analytical and advisory activities (AAA) and TA for impact assessments and review of the evidence base Lending and financing Convening role facilitating national and regional policy dialogues to prevent spread of climate-sensitive diseases
Ecosystems and biodiversity	Quantitative and qualitative damage to freshwater, coastal, marine, and terrestrial ecosystems with consequences for livelihoods Loss of habitats, dependent species, and important ecological goods and services Biodiversity loss in the Himalayas, glacier-fed ecosystems, forests, and coral reefs Shifts in vegetation regimes in forests, grasslands, and semi-arid deserts resulting in altered community structures and climate feedbacks	Expansion of protected area networks and promotion of ecosystem-based approach in biodiversity conservation Mainstreaming of biodiversity and ecosystem management in development projects, low-carbon growth, adaptation and risk management Designing and building biodiversity-friendly and climate-resilient infrastructure Generation of knowledge and capacity	Financing for arresting and reversing ecosystem degradation, especially in biodiversity hotspots Pilot new approaches for protecting, upgrading, restoring, sustaining and expanding ecosystems – Payment for Ecosystem Services, Debt for Nature Swap Increasing the AAA and TA portfolio for building knowledge and capacity, particularly of the regulatory agencies
Urban	Climate-related damage to urban settlements, lives, assets, and basic water and sanitation services Increase in urban vector- and water-borne diseases (associated with urban poverty, mainly in slums) Growth of greenhouse gas emissions of future urbanization	Integration of climate adaptation and disaster risk management within the urban climate change strategy Harnessing potential for low-carbon growth in industries such as solid waste, wastewater treatment, energy-efficient buildings and infrastructure Improving energy-efficient buildings	Technical, financial and capacity building support on adaptation and risk management in urban areas Building knowledge and capacity of cities to adopt mitigation strategies and in developing urban climate change agenda Assist cities in integrating urban transport, energy and construction within urban climate change strategy Supporting the improvement of urban water infrastructure and sanitation services and demand management

Role of the World Bank

The main objective of the World Bank is to support the development priorities of countries in South Asia by addressing climate change related risks and harnessing development opportunities that promote low-carbon growth. Agreements on global climate strategies to stabilize emissions lie in the jurisdiction of the Parties to the UNFCCC, at which the World Bank is a neutral observer and does not participate. However, the Bank recognizes that climate change has become a significant development challenge that threatens growth prospects.

Building country ownership, capacity and awareness is the key to tackling the climate change problem. In developing its approach to the climate problem the World Bank (Bank) recognizes that the resources available for climate change are limited, while the region is a large player whose performance will have an important bearing on global outcomes. Simply strengthening or scaling-up the many climate-friendly investments in the Bank's portfolio will not be sufficient to tackle the problem. For the Bank's interventions to be effective the solution lies in building partnerships to promote country ownership of climate change challenges.

Adaptation to climate change lies at the heart of the Bank's priorities, because it is critical in reducing climate-related threats to development. With rapid economic progress in recent decades, there also remain wide opportunities for catalyzing low-carbon growth across the region in ways that contribute to the overall development objectives of South Asian countries. Table 5.4 provides examples of some initiatives to address the major climate risks identified in each country.

Effective adaptation poses many policy challenges. Responses have to be developed in the face of uncertainties on the timing, location and severity of climate impacts. Confronted with the large uncertainties, a rational first response is to invest in greater knowledge to better understand the scale and magnitude of these threats and to build institutional capacity and knowledge to adequately respond to the challenges. The Bank has pioneered analytical work to identify climate risks and adaptation needs in select drought and flood prone areas in India (World Bank 2008). An innovative project in India – the Andhra Pradesh Drought Adaptation Initiative - is successfully piloting the approaches identified in previous Bank reports. There is a growing portfolio of activities that explores other key climate risks including the cross-border problems posed by glacial retreat in the Himalayas, sea level rise and impacts on agriculture and water resources. An environmental project in the Maldives aims to build natural climate resilience through better information and management of marine resources. The aim of the Bank's work is to develop approaches that would catalyze the integration of climate risks in country programs and plans.

Most greenhouse gas emissions in South Asia derive from the use of fossil fuels. The Bank's energy portfolio is already well structured to promote low carbon growth in the region. There is a growing emphasis on promoting energy efficiency, renewable energy and institutional reforms aimed at improving energy service and efficiency. A Low Carbon Growth study for India

identifies the low-hanging fruits for harnessing emission reductions in ways that promote broader development objectives. In the transport sector a multipronged approach promotes integrated transport planning in ways that are conducive to growth and lowering the emission profile. A robust and growing carbon finance portfolio identifies and promotes emission reductions across myriad sectors including the small and medium industries, forestry, the power sector and transport.

The Bank is also active in assisting countries leverage additional resources as these become available. A landmark Multi-Donor Trust Fund for climate change is under negotiation in Bangladesh and the Bank is active in implementing the Pilot Program for Climate Resilience in Nepal and Bangladesh. Responding to country demands assistance is also provided to prepare for global negotiations and protocols.

Conclusions

Many policy options to address climate risks are already well known. Improved natural resource management, energy efficiency, preventative approaches to disaster management and mechanisms to internalize environmental externalities – have all been studied and occasionally piloted. But implementing these still remains a challenge. Success often relies not just on the availability of finance, but on institutional incentives and the need to build country knowledge and ownership of the agenda. To address the climate challenge in South Asia will call for the integration of climate-friendly approaches in country development policies, plans, and programs, taking into account country risks, needs, demands, and institutional structures.

At the global level, South Asia is a large player whose performance on emission control and adaptation will have significant consequences. The current global regime has evolved through the UNFCCC and the Kyoto Protocol. It has catalyzed agreements to limit greenhouse gas emissions and it has created a carbon market to direct private investment and lower the costs of emission reductions. While these are significant achievements, experience suggests that the approach has limitations. Global emissions have increased by nearly 30 percent since the Kyoto Protocol came into force and the agreement has delivered little support to developing countries battling with adaptation challenges and the burdens of low-carbon growth imperatives. A stronger global commitment for climate actions is both a matter of need and equity. Climate impacts are already being felt globally and, the poor who have contributed the least to the problem face the gravest threats. If the climate challenge can only be met through collective action, the global regime must be inclusive and speak to the needs of developing countries. It should be more development-oriented, provide considerably greater funds to address the climate challenge and simultaneously promote inclusive growth in ways that limit emissions. These are formidable challenges for any global compact but would need to be addressed if there is to be a durable and effective solution to the global climate challenge.

Appendix. Country Profiles

The information on observed and projected climate trends in the following profiles has been drawn mostly from official government sources including, where available, the Initial National Communications of South Asian countries to the UNFCCC and the National Action Programs of Adaptation (NAPAs) of countries that have one (i.e. Bhutan, Maldives and Bangladesh). In cases where this information is unavailable or incomplete, additional sources were reviewed to compare and complement these sources. All sources are noted in the profiles whenever applicable.

The information in this appendix is meant to provide a general outlook on climate change issues and trends of countries in South Asia. Climate projections reported in the sources consulted were derived by third parties using different climate models and scenarios. They are not comparable and should be taken only as indicative projections rather than precise forecasts.

Afghanistan

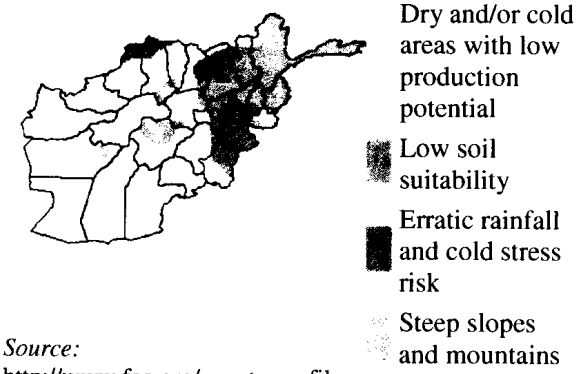
Afghanistan is a mountainous and very arid country in South Asia. Agriculture is the primary source of productivity and livelihood in the country, accounting for 48 percent of GDP and 85 percent of total employment. Prolonged drought and violent conflict have limited its development and have caused extensive degradation of its natural and physical capital, limiting its future growth opportunities and capacity to adapt to climate shocks. The rapid loss of forest and plant cover over the last 25 years has accelerated soil erosion and land degradation in the country, making it susceptible to landslides, flash floods, and extreme flooding events. Human development indicators in the country are among the lowest in the world. Water shortages, desertification, and future environmental degradation, which are impending threats of climate change.

Observed Climate Trends

Afghanistan has experienced an increase in temperature and frequency of hot days and nights since 1960. Average temperature has increaseed by 0.6°C and there were 25 more hot days and nights observed than usual (UNDP 2008a).

A shortfall in precipitation of 2 percent per decade has led to prolonged drought conditions in the country. Rainfall has become scarcer, particularly during the months of March to May, declining by 6.6 percent per decade since 1960 (UNDP 2008a).

Afghanistan is also at risk from drought, cyclones, and floods.



Source: http://www.fao.org/countryprofiles/Maps/AFG/04/ec/index.html (accessed November 24, 2008).

Indicators

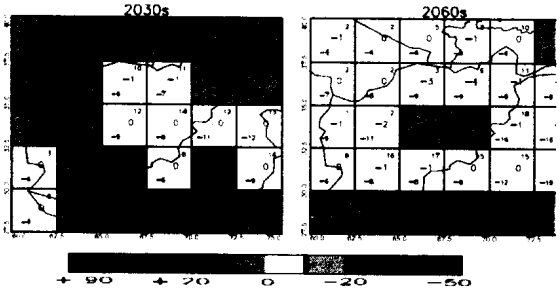
GDP: US$10.14 billion (2007)*
GNI per capita: US$190 (2004)
Population: 28.6 million (2004); urban 23.8%
Land area: 652,000 sq. km
Agricultural land (% total): 58.3
Irrigated land (% of cropland): 33.8
Forest area (% of land area): 1.3

Sources: World Bank 2006; *World Bank 2008c.

Projected Future Climate Trends

Global climate models predict that the country will experience a warming of 1.4°C to 4°C by the 2060s and 2.0°C to 6.2°C by the 2090s. Projections indicate substantial increases in the frequency of days and nights that are considered "hot" by current climate standards. Days considered "hot" will occur on 14–25 percent of days by the 2060s and on 16–32 percent of days by the 2090s. Cold days and nights, on the other hand, will become rarer, occurring on 0–6 percent of days by the 2090s (UNDP 2008a).

Projected Annual Rainfall Changes



Source: Reproduced with permission from UNDP 2008a.

The increase in temperature will be accompanied by a reduction in annual rainfall, particularly in the wettest season. Mean annual precipitation will decline by 10 percent in 2030–2049 compared to the 1980–1999 level. The changes in temperature and rainfall will reduce annual runoff by 24 percent by mid-century (UNDP 2008a).

Greenhouse Gas Contribution

2000 Emissions from Land Use Change and Forestry

Emissions (million metric tons of CO_2)	Per capita emissions (metric tons of CO_2 per person)
8.8	0.3

Source: Climate Analysis Indicators Tool (CAIT) Version 6.0 (Washington, DC: World Resources Institute, 2009) (http://cait.wri.org/cait.php, accessed March 10, 2009).

Key Climate Change Risks

Main Vulnerabilities

- *Water Resources*
  Water scarcity due to reduced precipitation, increased evapotranspiration, and long-run depletion of water supplies from glacier-fed rivers
- *Agriculture and Ecosystems*
  Exposure of agriculture (pasture), wetlands, and other ecosystems to drought and desertification
- *Natural Disasters*
  Flooding from glacial melt, drought, and desertification

Main Vulnerabilities (continued)

- *Public Health*
  Increasing risk from malaria
- *Social Development*
  Food insecurity, malnutrition, and possible migration and conflict

Low-Carbon Growth Issues

- Continued reliance upon fuelwood for primary energy supply (85–97 percent)
- Growth of emissions from land use changes and deforestation due to population growth and conflict

Bangladesh

Bangladesh is one of the most populous countries in South Asia. The country is composed largely of low-lying lands less than 6 meters above sea level. About 80 percent of its lands are floodplains and are thus prone to flooding. It is also frequently visited by extreme climatic events, causing damage to life, property, and the economy. The country's geographic location, low elevation, high population density, poverty incidence, and dependence upon natural resources and services render the country particularly vulnerable to future climate change. Over 92 percent of the runoff that comes into Bangladesh enters from the outside (Government of Bangladesh, Ministry of Environment and Forests 2005), which highlights the importance of dialogue and regional cooperation to manage water inflows. Increased precipitation, rapid glacial retreat in the Himalayas, and rise in sea level will increase the likelihood of flooding in the future. Some areas of the country are also at high risk from drought.

Source:
http://www.fao.org/countryprofiles/Maps/BGD/04/ec/index.html (accessed November 24, 2008).

Indicators

GDP: US$567.69 billion (2007)*
GNI per capita: US$470*
Population: 158.57 million (2007)*; urban 24.6% (2004)
Land area: 130,000 sq. km
Agricultural land (% of area): 69.2
Irrigated land (% of cropland): 56.1
Forest area (% of land area): 6.7

Sources: World Bank 2006; *World Bank 2008c.

Observed Climate Trends

The available data indicate that the temperature has increased in the summer monsoon. The annual mean maximum temperature showed a significant increase in the 1961–1990 period (at 0.05°C per year). Likewise, cyclone frequency over the Bay of Bengal increased significantly in the months of November and May (Government of Bangladesh, Ministry of Environment and Forests 2005). Rainfall also increased and became more irregular. Serious, recurring floods have taken place regularly.

Data from the SAARC Meteorological Research Centre indicate that sea level rose at a rate many times higher than the mean rate of global sea level rise over 100 years (Government of Bangladesh, Ministry of Environment and Forests 2005). This has led to coastal inundation, erosion, saline intrusion, loss of biodiversity and agricultural land, and migration.

Projected Future Climate Trends

Global climate model projections indicate a significant increase in temperature and rainfall in Bangladesh in coming decades, in both the monsoon and winter seasons. Annual mean temperature is expected to increase by 1°C by 2030 and by up to 2.4°C by 2100, and precipitation by 5 percent by 2030 and 10 percent by 2100, with the increase being more pronounced during the summer monsoon (Government of Bangladesh, Ministry of Environment and Forests 2005). A significant increase in runoff is expected in the order of 20 to 30 percent by mid-century (Milly, Dunne and Vecchia 2005), leading to more flooding.

Bangladesh will be vulnerable to more intense storm surges and cyclones. The future rise in sea level will further exacerbate storm surge damage and riverbank erosion (Government of Bangladesh, Ministry of Environment and Forests 2005).

Current Greenhouse Gas Contribution

2005 Emissions[a]

Greenhouse gas emissions (million metric tons of CO_2)	Per capita emissions (metric tons of CO_2 per person)	Emission intensity (metric tons of CO_2)[b]
143.2	0.9	874.5

a. Does not include emissions from land use changes or forestry sector since data were not available for this year.

b. GDP measured in constant currency using 2005 as the base year.

Source: Climate Analysis Indicators Tool (CAIT) Version 6.0 (Washington, DC: World Resources Institute, 2009) (http://cait.wri.org/cait.php, accessed March 10, 2009).

Key Climate Change Issues

Main Vulnerabilities

- *Agriculture*
  Lower agricultural output and incomes, and food insecurity through diminished yields and loss of land
- *Ecosystems*
  Loss of biodiversity, particularly in coastal ecosystems – Sundarbans at high risk, increased sea temperatures of 2°C above long-term average, and reduced fishery production
- *Water Resources*
  Freshwater stress, groundwater depletion, and reduced fish aquaculture production
- *Disasters and Other Hazards*
  Exposure to more intense cyclones and drought in some areas, combined impacts of sea level rise and glacial melt leading to increased incidence of flooding and land loss

Main Vulnerabilities (continued)

- *Public Health*
  Increased incidence of heat-related illnesses, water-borne diseases, poverty, child and infant mortality; lower access to safe water and sanitation, loss of settlements and damages to infrastructure, possible migration

Low-Carbon Growth Issues

- Increased coal dependence (risks of early transition to coal)

Other sources consulted: Government of Bangladesh, Ministry of Environment and Forests 2002.

Bhutan

Bhutan is one of the smallest countries in South Asia, but has the most abundant forest and water resources in the region. It is considered a sanctuary for biodiversity and a model of environmental stewardship. Reflecting the high productivity of its natural capital the country is unique in having almost graduated to middle income status with a large proportion of its population engaged in subsistence agriculture. Other sources of growth include ecotourism, and hydropower sold mainly to India. The country is landlocked, and agriculture contributes to a fifth of its economy. Climate change presents many threats to Bhutan. The retreat of glacier cover in recent decades has already led to the formation of supra-glacial lakes and to breaches in the critical geostatic thresholds of several glaciers. The risk of glacier lake outburst floods will increase as the rate of glacier melt accelerates in the future. Steep slopes and heavy monsoon rains also render the entire country susceptible to flash floods and landslides.

Source: http://www.fao.org/countryprofiles/Maps/BTN/04/ec/index.html (accessed November 24, 2008).

Indicators

GDP: US$1.10 billion (2007)*
GNI per capita: US$1,770 (2007)*
Population: 0.66 million (2007)*; urban 8.8%
Land area: 47,000 sq. km
Agricultural land (% of total): 12.6*
Forest area (% of land area): 68

Sources: World Bank 2006; *World Bank 2008c.

Observed Climate Trends

Weather stations were established in Bhutan only in 1973. Therefore, no long-term climate data have been gathered. In the 1990–2002 period the available data point to an increase in precipitation variability across the country. In the 1998–2003 period, the mean monthly temperature recorded was higher than the mean temperature recorded for the 1990–2003 period, pointing to an overall warming trend (National Environment Commission, Royal Government of Bhutan 2000).

The increase in temperatures in recent decades has led to a reduction in Bhutan's glacial cover. Some glaciers in Bhutan have been receding at a rate of 30–60 meters per year (ICIMOD 2001 in National Environment Commission, Royal Government of Bhutan 2000). In addition

Projected Future Climate Trends

A significant increase in temperatures is predicted through the early to the middle of the 21st century ranging from 0.2°C up to 4°C, depending on the season. The highest increase is predicted for the winter months, when increases of 1.5°C to 4°C may occur by the 2050s (Adaptation Learning Project, http://www.adaptationlearning.net/profiles/country/country.php?id=BT, accessed March 9, 2009).

Both coarser and higher-resolution climate models predict an increase in precipitation in Bhutan as follows:

	Dec–Feb	Jun–Aug
2020s	−15 to +18%	+2 to +12.5%
2050s	−15 to +20%	+5 to +20%

Source: Adaptation Learning Project (http://www.adaptationlearning.net/profiles/country/country.php?id=BT, accessed March 9, 2009).

Precipitation will become more intense and erratic, while glaciers continue to melt, both exacerbating the risk of floods. Runoff will also increase as a result of the changes in rainfall intensity.

to the increased risk of glacial lake outburst floods, the country has become increasingly vulnerable to floods, cyclones, landslides, and drought.

Current Greenhouse Gas Contribution

2005 Emissions[a]

Greenhouse gas emissions (million metric tons of CO_2)	Per capita emissions (metric tons of CO_2 per person)	Emission intensity (metric tons of CO_2)[b]
0.4	0.6	178.1

a. Does not include emissions from land use changes or forestry sector since data were not available for this year. Data not available for emissions of CH_4, N_2O, PFC, HFC, SF_6, international bunkers.

b. GDP measured in constant currency using 2005 as the base year.

2000 Emissions from Land Use Change and Forestry

Emissions (million metric tons of CO_2)	Per capita emissions (metric tons of CO_2 per person)
0	0

Source: Climate Analysis Indicators Tool (CAIT) Version 6.0 (Washington, DC: World Resources Institute, 2009) (http://cait.wri.org/cait.php, accessed March 10, 2009).

Key Climate Change Issues

Main Vulnerabilities

- *Agriculture*
  Reduced agricultural production
- *Water Resources*
  Water shortage and groundwater depletion
- *Ecosystems and Biodiversity*
  Loss of forest area or production, threat of biodiversity loss
- *Natural Disasters*
  Exposure to glacial lake outburst floods, flooding, and drought
- *Public Health*
  Increase in incidence of vector-borne diseases, malaria in particular, and water-borne diseases such as gastroenteritis and diarrhea

Low-Carbon Growth Issues

- Increased fuelwood consumption due to population growth

Opportunities

- Renewable energy technologies: hydels, solar and biomass gasifiers

Highlights from Bhutan's National Adaptation Program of Action (NAPA)

The Royal Government of Bhutan's National Adaptation Program of Action (NAPA) recognizes that Bhutan is highly vulnerable to climate change. The following factors are among those that render the country vulnerable: the existence of fragile mountain ecosystems; a great reliance on subsistence agriculture and farming of dryland crops; a population whose growth rate is among the highest in the world (2.5–3 percent); and a high dependency on both monsoon rains (70 percent of the country's rainfall falls during the monsoon season) and export of hydropower, which accounts for about 12 percent of GDP. With its fragile ecosystem, glacier lake outburst floods in the northern mountains constitute an ever-present threat. Of the 2,674 glacial lakes that exist in Bhutan, 24 are considered to be potentially dangerous. Thus, predicted increases in temperature and more erratic rainfall patterns pose a threat to Bhutan, its people, and its economy.

The NAPA process was highly consultative in nature; it led to the identification and prioritization of nine adaptation projects out of an original list of 55 projects, as follows:

1. Disaster Management Strategy (Pilot Implementation of Food Security and Emergency Medicine)
2. Artificial Lowering of Thorthomi Glacier Lake
3. Weather Forecasting System to Serve Farmers and Agriculture
4. Landslide Management and Flood Prevention
5. Flood Protection of Downstream Industrial and Agricultural Area
6. Rainwater Harvesting
7. GLOF Hazard Zoning (Pilot Scheme – Chamkar Chu Basin)
8. Installation of Early Warning System on Pho Chu Basin
9. Promote Community-based Forest Management and Prevention

Source: National Environment Commission, Royal Government of Bhutan, n. d.

India

India is the largest country and leading economy in South Asia. Its unique geography produces a spectrum of climates and a rich array of biological diversity. Its climate regime varies from humid in the northeast to arid in Rajasthan. Climate change presents many risks to such a geographically diverse country, from increased exposure to floods, drought, cyclones, and sea temperature rise to new threats of sea level rise and ocean acidification. With a huge population that ranks second in size in the world, India will be highly vulnerable to climate change.

Observed Climate Trends

Over the 20th century there was an increase in temperature of around 0.4°C, primarily due to an increase in maximum temperatures, mainly in the post-monsoon and winter seasons. The trend to warmer temperatures has been most marked along the west coast, in central India, in the interior peninsula, and in northeast India. On the other hand, northwest India and a small region in the south have experienced a cooling trend.

Monsoons exhibit considerable variability in the past but with a stable core. Average monsoon rainfall across the country has varied by region, with an increase in monsoon seasonal rainfall of 10 to 12 percent recorded along the west coast, northern Andhra Pradesh, and the northwest; and a reduction in east Madhya Pradesh, the northeast, and parts of Gujarat and Kerala.

On average, 19 percent of the country experiences arid conditions every year, mostly in northeast India. Between 1965 and 1990, the average number of cyclonic storms per year was 2.3 [7] (Government of India, Ministry of Environment and Forests 2004).

Indicators

GDP: US$1,170 billion (2007)*
Population: 1.12 billion (2007)*; urban 28.5% (2004)
GNI per capita: US$950 (2007)*
Land area: 3,287, 000 sq. km*
Agricultural land (% total): 60.6*
Irrigated land (% of cropland): 33
Forest area (% of land area): 22.8

Sources: World Bank 2006; *World Bank 2008c.

Projected Future Climate Trends

Using the Hadley Centre high-resolution model (HadRM2) for the IS92a scenario[8] of greenhouse gas emissions, a general increase in temperature is expected through the 2050s, with significant warming of beyond 4°C expected by 2050 in the north. In the south, warming will range between 2°C and 4°C.

Insignificant changes in monsoon rainfall are projected up to the 2050s, but an overall decrease in the number of rainy days over a major part of the country is expected. The reduction in rainfall days will be greater in the western and central parts (by more than 15 days). The Himalayan foothills and the northeast may experience increases of 5 to 10 rainfall days. Rainfall intensity will also vary geographically, increasing by 1–4 millimeters/day in most areas of the country and declining by 1 millimeter/day in small areas of the northwest. While the precipitation changes will be less certain, the El Niño southern oscillation will remain a key driver of variability. Though varying in the magnitude and spatial results, all climate models (global and regional) predict an increase in overall temperature in the 21st century and most agree that precipitation will increase during the monsoon season. (Government of India, Ministry of Environment and Forests 2004).

[7] Between 1891 and 1990 the number was 1.3. It is unclear whether this reflects an actual increase in the frequency or an improvement in the technology used to monitor these events.

[8] Six IS92 scenarios were created by IPCC after the release of its First Assessment Report (1992). IS92a came to be widely adopted as a standard scenario used in impact assessments. It assumes an increase in the rate of anthropogenic greenhouse gases equal to a compounded 1 percent per year relative to 1990 values.

Current Greenhouse Gas Contribution

2005 Emissions[a]

Greenhouse gas emissions (million metric tons of CO_2)	Per capita emissions (metric tons of CO_2 per person)	Emission intensity (metric tons of CO_2)[b]
1,863.4	1.7	763.4

a. Does not include emissions from land use changes or forestry sector since data were not available for this year.

b. GDP measured in constant currency using 2005 as the base year.

Source: Climate Analysis Indicators Tool (CAIT) Version 6.0 (Washington, DC: World Resources Institute, 2009) (http://cait.wri.org/cait.php, accessed March 10, 2009).

Key Climate Change Issues

Main Vulnerabilities

- *Coastal and Marine Ecosystems*
  Exposure to sea level rise, sea temperature increases, cyclone incidence
- *Water Resources*
  Impact of glacial melt, increased temperature, reduction in runoff, precipitation changes, extreme weather events, and saline intrusion in coastal regions
- *Public Health*
  Increased heat-related illnesses and water-borne diseases and changes in epidemiological patterns
- *Agriculture*
  Exposure of agriculture to extreme weather events, more variable precipitation, and changes in glacial cover
- *Natural Disasters*
  Increased exposure to flood, drought, and cyclones

Main Vulnerabilities (continued)

- *Terrestrial Ecosystems*
  Vegetation shift in forests and biodiversity, regime shifts in rangelands, decreased agricultural yields in tropics and subtropics, impact of glacial melt on biodiversity and low-lying agriculture
- *Urban*
  Impacts on urban infrastructure, including drainage, water, and sanitation

Low-Carbon Growth Issues

- Increased emissions from energy production and transformation, and from transport, urban, agricultural, industrial, and residential sectors due to economic growth and urbanization
- Impact of climate change upon carbon sequestration capacity of forest ecosystems, other biomass, and soils

National Action Plan on Climate Change and National Missions

India's Prime Minister released that country's first National Action Plan on Climate Change (NAPCC) in June 2008. The plan outlines existing and future policies and programs that address climate mitigation and adaptation. It argues that these national measures would be more successful with assistance from developed countries and pledges that India's per capita greenhouse gas emissions "will at no point exceed that of developed countries even as we pursue our development objectives".

The plan directs responsible ministries to submit detailed implementation plans to the Prime Minister's Council on Climate Change. The council will review and report on the progress accomplished during implementation and it will develop adequate indicators to measure progress and impact. The plan also identifies eight core "national missions" running through 2017, as follows:

1. **Solar Mission.** This mission aims to promote the development and use of solar energy for power generation and other uses, as well as to render solar energy competitive with fossil-based energy options in urban areas, industry, and commercial establishments. Its goal is to generate at least 10,000 megawatts of solar thermal power and to create a solar research center, among other things.
2. **Mission for Enhanced Energy Efficiency.** This mission seeks to yield savings of 10,000 megawatts by 2012 through the implementation of certain initiatives, such as energy incentives (including differential taxation on energy-efficient appliances); setting up financing platforms for public-private partnerships to reduce energy consumption through demand-side management programs; and establishing a system for large energy-intensive industries and facilities to trade energy-savings certificates so that they can meet government-mandated reductions in energy consumption, as per the Energy Conservation Act.
3. **Mission on Sustainable Habitat.** This mission seeks to promote energy efficiency in urban planning through measures such as putting more emphasis on urban waste management and recycling; strengthening the enforcement of automotive fuel economy standards, using pricing measures to encourage the purchase of fuel-efficient vehicles; and providing incentives for people to make greater use of public transportation.
4. **Water Mission.** This mission aims to increase water use efficiency by 20 percent through pricing and regulatory measures, including recycling of wastewater, increases in irrigation efficiency, and incentives to promote water-neutral or water-positive technologies and groundwater recharge.
5. **Mission for Sustaining the Himalayan Ecosystem.** This mission seeks to promote the conservation of biodiversity, forest cover, and other ecological values in the Himalayan region to help stop the retreat of glaciers, as they constitute a major source of India's water supply.
6. **Mission for a "Green India".** The mission plans to expand forest cover in India by 10 percent by afforesting 6 million hectares of degraded forest lands.
7. **Mission for Sustainable Agriculture.** The mission will foster adaptation in the agricultural sector by supporting the development of climate-resilient crops and the expansion of weather insurance mechanisms, among other measures.
8. **Mission on Strategic Knowledge for Climate Change.** This mission will promote "a better understanding of climate science, impacts and challenges". It calls for the establishment of a new Climate Science Research Fund, improved climate modeling, and increased international collaboration. It will also foster private sector initiatives aimed at developing adaptation and mitigation technologies through venture capital funds.

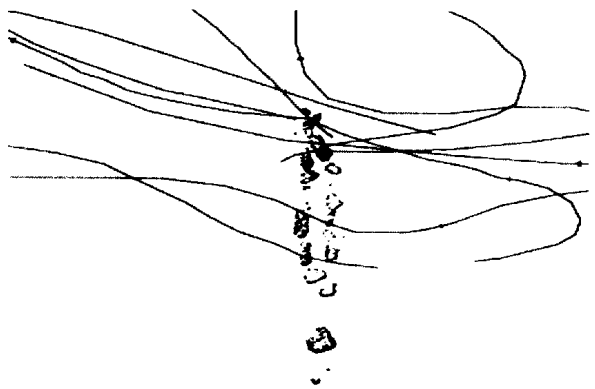
Source: Adapted from Pew Center on Global Climate Change, 2008.

Maldives

Maldives comprises coral atolls and hundreds of smaller islands and has more territorial sea than land. The coral reefs that surround the atolls are the seventh largest in the world and among the richest in terms of biodiversity and aesthetic value. About 70 percent of its GDP is based upon the tourism and fishery revenues derived from its marine resources.

With about 80 percent of the country lying below 1 meter above the sea, the country is exposed to the risks of extreme weather events, coastal inundation due to sea level rise, and saline intrusion.

Changes in sea temperature have also resulted in coral bleaching and mortality, most severely in areas affected by pollution and physical disturbance.



Cyclone tracks over Maldives between 1877 and 2004

Source: Ministry of Environment, Energy and Water (MEEW), Republic of Maldives 2007.

Indicators

GDP: US$1.05 billion (2007)*
GNI per capita: US$3,200 (2007)*
Population: 0.31 million (2007)*; urban 29.3% (2004)
Total area: 300 sq. km
Agricultural land (% total): 47

Sources: World Bank 2006; *World Bank 2008c.

Observed Climate Trends

No significant long-term trends were observed in daily, monthly, or annual rainfall in Maldives over the period 1989 to 2005. However, an increase in sea surface temperature has been observed near the Maldives coast at South Gan and Malé. Annual sea surface temperature increases at Malé and Gan are about 0.2°C and 1.1°C to 1.6°C, respectively, per decade. Sea surface temperature and mean tide level at Hulhulé weather station, which provide a general indication of current climate risks for Maldives, have consistently increased during all seasons.

Data from Hulhulé also indicate a sea level increase of 1.7 millimeters per year from 1989 to 2005. The maximum hourly sea level rise was 7 millimeters per year, far in excess of local and global trends in mean sea level. The maximum storm surge height was 1.32 meters, which, coupled with a high tide, could generate a storm surge of 2.3 meters. The northern part of the country is vulnerable to severe weather

Projected Future Climate Trends

The Maldives' National Adaptation Program of Action (2007) identified four major climate-related hazards for the Maldives: (i) sea level rise, (ii) precipitation changes, (iii) temperature changes, and (iv) extreme events. A summary of predictions for each hazard is presented below.

Sea level rise	**Precipitation**
By 2050, an hourly sea level of 70 centimeters above mean sea level may become at least an annual event at Hulhulé, whereas currently it is a once in 100 years event.	By 2050 both extreme daily rainfall (180 millimeters) and extreme three-hour rainfall events (100 millimeters) are expected to occur twice as often in the same timeframe (currently 100 years and 25 years, respectively).
Temperature	**Extreme events**
• By 2025 the maximum temperature of 33.5°C – currently a once in 20 years event – will become a once in 3 years event. • By 2100 the annual	• Even under a medium sea level rise scenario of 0.48 meters, tidal inundations would become regular events in almost all islands. • By 2025, extreme wind gusts of 60 knots are

events, particularly storms generated by cyclones in other regions. *Source:* Government of the Republic of Maldives, Ministry of Environment, Energy and Water (MEEW) 2007.	maximum temperature is projected to increase by around 1.5°C.	forecasted to occur more frequently – currently a once in 16 years event, this will likely become a once in nine years event. (UNDP Disaster Risk Profile for the Maldives 2006 in MEEW 2007) • The intensity of tropical cyclones will increase by 10–20 percent (Nurse and Sem 2001 in MEEW 2007)

Current Greenhouse Gas Contribution

2005 Emissions[a]

Greenhouse gas emissions (million metric tons of CO_2)	Per capita emissions (metric tons of CO_2 per person)	Emission intensity (metric tons of CO_2)[b]
0.7	2.4	605.6

a. Does not include emissions from land use changes or forestry sector since data were not available for this year. Data not available for emissions of CH_4, N_2O, PFC, HFC, SF_6, international bunkers.

b. GDP measured in constant currency using 2005 as the base year.

Source: Climate Analysis Indicators Tool (CAIT) Version 6.0 (Washington, DC: World Resources Institute, 2009) (http://cait.wri.org/cait.php, accessed March 10, 2009).

Key Climate Change Issues

Main Vulnerabilities

- *Coastal and Marine Ecosystems*
  Ecosystem damage and loss of protection afforded by coral reefs
- *Water Resources*
  Increased salinity of groundwater resources
- *Public Health*
  Risk of loss of life due to disasters and increased incidence of vector-borne diseases
- *Tourism*
  Reduced tourism revenues and livelihoods
- *Disasters and Hazards*
  Physical damage from increased incidence of cyclones and flooding and inundation of islands due to sea level rise

Main Vulnerabilities (continued)

- *Social Impacts*
  Possible migration and large-scale relocation (40 percent of all housing structures, which serve as dwellings for 42 percent of the population, are located within 100 meters of the coastline. This close proximity puts them at high risk of inundation under any sea level rise scenario (Government of the Republic of Maldives, Ministry of Environment, Energy and Water 2007).

Other sources consulted: Government of the Republic of Maldives, Ministry of Home Affairs, Housing and Environment 2001.

Nepal

Nepal is a small landlocked mountainous country located between China and India. Its topography varies widely from the very high altitudes of the Himalayan mountain range to the Gangetic plains in its southeast. Agriculture is the main source of its economic productivity, providing livelihoods to over 80 percent of the population. The country is one of the richest in terms of water resources, as about 16 percent of the Himalayan glacial cover is found in its mountain ranges. Its mountains also contain remarkable biodiversity. Eight of the 10 highest mountain peaks in the world are located in the country and around 4.3 percent and 8.5 percent of the world's mammalian and bird species, respectively, are found in this small country.

Future climate changes could have serious implications for the country's agriculture, water, forest resources, and biodiversity.

Source: http://www.fao.org/countryprofiles/Maps/NPL/04/ec/index.html (accessed November 24, 2008).

Indicators

GDP: US$10.21 billion (2007)*
Population: 28.11 million (2007)*; urban 15.4% (2004)
GNI per capita: US$340 (2007)*
Land area: 147,200 sq. km*
Agricultural land (% of land area): 29.5*
Irrigated land (% of cropland): 47
Forest area (% of land area): 25.4

Sources: World Bank 2006; *World Bank 2008c.

Observed Climate Trends

Some studies suggest that from 1960–2003 there have been no observed annual temperature increases over Nepal. There has been a small but significant increase in the frequency of hot nights and a significant decline in the annual frequency of cold days and nights, by 19 days and 32 nights. Hot nights have also increased by 2.5 percent (UNDP 2008b).

Annual precipitation has significantly decreased by an average of 3.7 millimeters per month per decade. However, the magnitudes of 1-day and 5-day rainfall maxima have shown significant increases during December to February and March to May over the same period (UNDP 2008b).

Nepal's Initial Communication to UNFCCC (Government of Nepal, Ministry of Population and Environment 2004) states that between 1981 and 1998 the overall temperature increased at 0.41°C per decade and that annual precipitation decreased by 9.8 millimeters per decade. The country has become more exposed to the risk of flooding, with resulting mortality outcomes increasing significantly since 1970 (EM-DAT: The OFDA/CRED International Disaster Database).

Projected Future Climate Trends

Global climate models predict that the country is expected to become warmer and wetter, with more frequent heatwaves and less frost. Average temperature is predicted to rise significantly by 1.3°C to 3.8°C by 2060 and by 1.8°C to 5.8°C by 2090. Winter months have a more rapid projected rate of warming than summer months. The number of days and nights considered hot by current climate standards is projected to increase, occurring on 11 to 28 percent of days and on 18 to 28 percent of nights by the 2060s. The greatest increase is projected to occur during the months of June to August (UNDP 2008b).

Projected changes for annual precipitation range from –13 millimeters (–27 percent) to +32 millimeters (31 percent). These changes in precipitation and the rapid decline in glacial cover will increase runoff by between 10 and 20 percent by mid-century (Milly, Dunne and Vecchia 2005). Total rainfall during heavy events is projected to increase (UNDP 2008b).

Current Greenhouse Gas Contribution

2005 Emissions[a]

Greenhouse gas emissions (million metric tons of CO_2)	Per capita emissions (metric tons of CO_2 per person)	Emission intensity (metric tons of CO_2)[b]
40.6	1.5	1,558.80

a. Does not include emissions from land use changes or forestry sector since data were not available for this year.

b. GDP measured in constant currency using 2005 as the base year.

2000 Emissions from Land Use Change and Forestry

Emissions (million metric tons of CO_2)
123.5

Source: Climate Analysis Indicators Tool (CAIT) Version 6.0 (Washington, DC: World Resources Institute, 2009) (http://http://cait.wri.org/cait.php, accessed March 10, 2009).

Key Climate Change Issues

Main Vulnerabilities

- *Water Resources*
  Glacier lake outburst floods and future desiccation of water resources due to rapid glacial melt
- *Public Health*
  Likely outbreaks of malaria and similar diseases
- *Agriculture*
  Decline in agricultural production in some areas
- *Terrestrial Ecosystems and Biodiversity*
  Impact of glacial melt upon dependent ecosystems and agriculture, and vegetation shift to forest biodiversity

Low-Carbon Growth Issues

- Impacts on carbon sequestration of vegetation shifts and forest productivity changes
- Land use changes due to future development
- Slash-burn agricultural practices

Other sources consulted: Thomas and Rai 2005.

Pakistan

Pakistan is the second largest country in South Asia and mainly comprises dry or cold areas with low production potential. Its geography varies across the country, shaping the great variation in its climate. Climate ranges from mild winters and hot, dry summers in the north to semi-arid and arid zones in the west and the south. The country is bounded by the Himalayas in the north, the mountain ranges of Safed Koh and Sulaiman in the east, and the lowland plains of the River Indus in its south, west, and coastal areas. Sixty percent of the total watershed area of the Indus basin lies within Pakistan's territory.

Climate change exposes these areas to risks of glacial melt, sea level rise, and drought. As more than half of its land area is arid and semi-arid, expected changes in temperature and rainfall patterns in the future could impinge upon its food security and the welfare of its millions of herders and pastoralists.

Indicators

GDP: US$143.60 billion (2007)*
Population: 162.39 million (2007)*; urban 34.5% (2004)
GNI per capita: US$870 (2007)*
Land area: 796,100 sq. km*
Agricultural land (%): 35.1*
Irrigated land (% of cropland): 90.6
Forest area (% of land area): 2.5

Sources: World Bank 2006; *World Bank 2008c.

Observed Climate Trends

Mean annual temperature has increased by 0.35°C since 1960, particularly during the months of October to December, when temperatures rose by 0.19°C per decade. The annual frequency of hot days and hot nights has also increased significantly since 1960, by 20 and 23 days respectively. The annual frequency of cold days and nights has decreased in the same time period: the former has declined by an average of 9.7 days and the latter by an average of 13 days (UNDP 2008c)

There have been no discernible changes, however, in the annual rainfall over Pakistan since 1960 or in the extremes observed for daily rainfall (UNDP 2008c).

Based on recorded data at Karachi for the 20th century, sea level rise was estimated to be occurring at a rate of 1.1 millimeters per year (Government of Islamic Republic of Pakistan, Ministry of Environment 2003).

The country has been exposed to high risks of flooding, cyclone events, and droughts, which have been associated with elevated mortality outcomes since the 1980s. The number of floods in particular increased five-fold between the 1980s and the 2000s (EM-DAT: The OFDA/CRED International Disaster Database).

Projected Future Climate Trends

Global Climate Change models predict a significant increase in annual temperature, which could induce biodiversity losses, changes in land use, and crop failure. The increase would be in the order of 1.4°C to 3.7°C by the 2060s and of 1.9°C to 6°C by the 2090s. Warming will be greater in the northern and high-altitude regions. The frequency of hot days and nights will also rise considerably (UNDP 2008c).

Global climate model projections for rainfall are highly inconsistent. Overall, projections on precipitation changes are within the range of –7 to +15 millimeters per month by the 2060s. There is greater consistency for projections of rainfall occurring in heavy events: models tend to predict a moderate increase, particularly during July to September (UNDP 2008c). The frequency and severity of cyclones is also likely to increase (Government of Islamic Republic of Pakistan, Ministry of Environment 2003).

Current Greenhouse Gas Contribution

2005 Emissions[a]

Greenhouse gas emissions (million metric tons of CO_2)	Per capita emissions (metric tons of CO_2 per person)	Emission intensity (metric tons of CO_2)[b]
243.7	1.6	716.1

a. Does not include emissions from land use changes or forestry sector since data were not available for this year.

b. GDP measured in constant currency using 2005 as the base year.

2000 Emissions from Land Use Change and Forestry

Emissions (million metric tons of CO_2)
33

Source: Climate Analysis Indicators Tool (CAIT) Version 6.0 (Washington, DC: World Resources Institute, 2009) (http://http://cait.wri.org/cait.php, accessed March 10, 2009).

Key Climate Change Issues

Main Vulnerabilities

- *Agriculture and Food Security*
  Increased intensity and frequency of drought and effects on agriculture (pasture)
- *Coastal Zones and Marine Ecosystems*
  Damages from sea level rise, erosion and increased storm events, exposure to changes in sea temperatures and water chemistry, particularly in the Indus delta
- *Water Resources*
  Initial flooding and future drying of water resources due to glacial melt and impact on water consumption
- *Land Resources*
  Reduced soil productivity, land use changes
- *Terrestrial Ecosystems*
  Impact of drought and future desiccation upon ecosystems (wetlands), particularly those that are glacier fed

Main Vulnerabilities (continued)

- *Natural Disasters*
  Increased incidence of storm events, droughts, and short-run flooding
- *Biodiversity*
  Reduction in alpine cover, loss of wetlands due to longer exposure to water logging
- *Health and Social Development*
  Outbreak of heat-related and insect-transmitted diseases, malnutrition, food and water insecurity, migration, and conflict

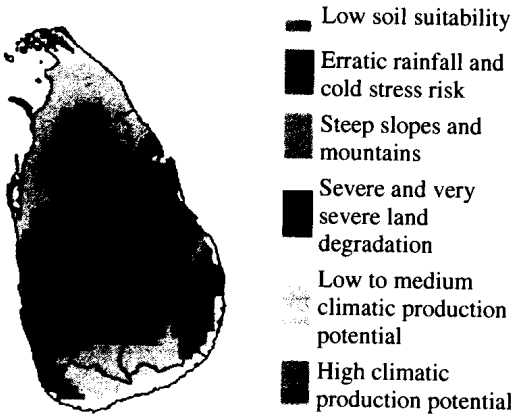
Low-Carbon Growth Issues

- Increased emissions from energy, transport, and urban sectors
- Emissions from agriculture and rangeland degradation

Sri Lanka

Sri Lanka is endowed with rich biodiversity, particularly in its mountain ranges and coastal areas. It is part of the Western Ghats biosphere and is one of the 36 global biodiversity hotspots. The country is hot and humid and has extensive areas with water deficit. Part of the country experiences dry spells that extend over several months, though the forest cover assures almost continuous water supply in these areas. In 2007, the country's economic activities were broadly divided into: services (58% of GDP), industry (30% of GDP), and agriculture (12% of GDP) (World Bank 2008c).

About 72 percent of its paddy production is situated in dry zones while 65 percent of industrial production and 80 percent of fish production are sourced from its coastal zone. The expected increases in temperature, frequency and duration of drought, intensity of rainfall and storm surges, and sea level will present tremendous risk to the country's economic productivity, human health, coastal settlements, and biodiversity.



Source:
(http://www.fao.org/countryprofiles/Maps/LKA/04/ec/index.html, accessed January 25, 2009).

Indicators

GDP: US$32.35 billion (2007)*
Population: 19.94 million (2007)*; urban 21.1% (2004)
GNI per capita: US$1,540 (2007)*
Land area: 65,600 sq. km*
Agricultural land (% total): 36.5*
Irrigated land (% of cropland): 39
Forest area (% of land area): 29.9

Sources: World Bank 2006; *World Bank 2008c.

Observed Climate Trends

The island experienced a warming of 0.48°C during 1960–1990, accompanied by an increase in thunder activity and a decline in precipitation, except in some isolated areas in the northwest. There has been an increase in variability in precipitation during 1960–1990 compared to 1930–1960. It has been estimated that 45 to 55 percent of Sri Lanka's coastline has experienced an erosion rate of 0.30–0.35 meters per year (Government of Sri Lanka 2000).

Sri Lanka is also prone to natural disasters, particularly cyclones and floods. In the period 1961–2004, cyclones and floods affected about 2 million and 9 million people, respectively. (EM-DAT: The OFDA/CRED International Disaster Database, http://www.em-dat.net/). Changes in sea temperatures have led to coral bleaching and loss of marine biodiversity.

Projected Future Climate Trends

Using the United Kingdom Hadley Centre for Climate Projection and Research Model (HadCM3) projections, average annual rainfall is projected to increase between 5 percent (B2) and 14 percent (A2) by 2050. The trend in spatial and seasonal precipitation, however, will vary, with dry zones expected to experience a reduction of 9 percent (B2) to 17 percent (A2) during the wet season (October–February). The wet season is also projected to come to an end earlier since there will be less rainfall in January and February. The average wet season temperature (i.e. the average of minimum and maximum air temperature) is projected to rise by as much as 1.6 ^{o}C (A2) and 1.3 ^{o}C (B2) (De Silva et al. 2007).

In 1998 it was estimated that an increase in sea level of 0.3 meters on the southwest coast could inundate as much as 41 square kilometers and result in the loss of 6 square kilometers of land (Government of Sri Lanka 2000).

Current Greenhouse Gas Contribution

2005 Emissions[a]

Greenhouse gas emissions (million metric tons of CO_2)	Per capita emissions (metric tons of CO_2 per person)	Emission intensity (metric tons of CO_2)[b]
13.8	0.7	197.7

a. Does not include emissions from land use changes or forestry sector since data were not available for this year. Data not available for emissions of CH_4, N_2O, PFC, HFC, and SF_6.

b. GDP measured in constant currency using 2005 as the base year.

2000 Emissions from Land Use Change and Forestry

Emissions (million metric tons of CO_2)
29.5

Source: Climate Analysis Indicators Tool (CAIT) Version 6.0 (Washington, DC: World Resources Institute, 2009) (http://cait.wri.org/cait.php, accessed March 10, 2009).

Key Climate Change Issues

Main Vulnerabilities

- *Agriculture and Food Security*
  Reduced crop yields due to temperature increase
- *Coastal Zones and Marine Ecosystems*
  Sea level rise – damage to settlements, industries, and livelihoods in coastal areas, ecosystem degradation and biodiversity loss in coastal and marine ecosystems
- *Water Resources*
  Salt water intrusion in freshwater and groundwater
- *Public Health*
  Increased incidence of vector-borne diseases such as malaria and risk of loss of life due to disasters
- *Terrestrial Ecosystems*
  Loss of forest biodiversity

Main Vulnerabilities (continued)

- *Fisheries and Marine Ecosystems*
  Threat of ocean acidification and increased incidence of cyclones upon fishery livelihoods; further coral reef bleaching
- *Disasters*
  Increased incidence of cyclone events and flood

Low-Carbon Growth Issues

- Release of stored forest carbon due to land use changes
- Increase in thermal power

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