SOUTH ASIA: SHARED VIEWS ON DEVELOPMENT AND CLIMATE CHANGE

THE WORLD BANK

South Asia Region Sustainable Development Department

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Shared Views on Development and Climate Change

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Glossary

adaptation. A process by which strategies to moderate, cope with, and take advantage of the consequences of climatic events are enhanced, developed, and implemented. Types of adaptation include anticipatory and reactive adaptation, private and public adaptation, and autonomous and planned adaptation.

adaptive measures or responses. Actions taken that result in building the capacity of communities and boosting their long-term resilience to climatic shocks or stress.

adaptation strategy. A broad plan of action that is implemented through policies and measures. Strategies can be comprehensive, focusing on national, cross-sectoral scales, or targeted, focusing on specific sectors, regions, or measures.

anemia. A condition that arises when the level of hemoglobin in the blood is less than 110 grams per liter (g/l) in pregnant women, and less than 120 g/l in nonpregnant women.

analytical and advisory activities. These are nonlending services offered to client countries by the World Bank. They are aimed at providing a foundation for defining strategic priorities and informing policy dialogue and decisions on projects and programs. The outputs of such activities range from reports on key economic and social issues to policy notes to knowledge-sharing workshops and conferences. Economic Sector Work, knowledge management, and training and learning are some of the main types of analytical and advisory activities.

anthropogenic. Resulting from activities of or produced by human beings.

basin. The drainage area of a stream, river, or lake.

C4 plant. A land plant that uses a so-called C4 fixation method to transform carbon dioxide into sugar. Chemically speaking, the method allows for binding the gaseous molecules to dissolved compounds inside the plant for sugar production through photosynthesis. C4 fixation is an improvement over the simpler and more ancient C3 carbon fixation strategy used by most plants. The intermediate compounds of the process contain four carbon atoms, hence the name C4.

carbon budget (also called **carbon balance).** A way of tracking the amount of carbon in ecosystems for policy analysis. It shows the inventory of carbon in carbon pools and the balance of exchange between the pools. For forests, this generally involves

multiplying inventory data collected at different times for trees, woody detritus, leaf litter, understory, and soil by conversion factors to express all units in terms of weight of carbon. Common units are million metric tons (MMT = teragrams = 10^{12} grams), metric tons (Mg = megagrams = 10^{6} grams), and billion metric tons (petagrams = 10^{15} grams). Carbon budgets or balances are often also calculated for individual plants in physiological terms, including photosynthesis, respiration, and allocation (which refers to the relative amount of carbon stored in specific organs) using time steps on the order of hours or days. Generally, the models producing these budgets are called process models, as they describe the process underlying the system under study (Heath and Joyce 1997).

carbon dioxide equivalent. A quantity that describes the global warming potential (GWP) in terms of an equivalent amount of carbon dioxide of a given mixture and amount of greenhouse gas over a specified time scale (generally 100 years). The carbon dioxide equivalency for a gas is obtained by multiplying the mass and the GWP of the gas. For example, the GWP for methane (CH_4) over 100 years is 25. This means that 1 million metric tons of methane emissions is equivalent to 25 million metric tons of carbon dioxide emissions. While it is a standard and useful metric for comparing emissions of different greenhouse gases, it does not imply the same climate change responses. The following units are commonly used:

- By the Intergovernmental Panel on Climate Change (IPCC): billion metric tons (gigatons) of CO_2 equivalent ($GtCO_2eq$)
- In industry: million metric tons of carbon dioxide equivalents (MMTCDE)
- For vehicles: grams of carbon dioxide equivalents per kilometer (gCDE/km)

carbon fertilization. The enhancement of the growth of plants as a result of increased atmospheric carbon dioxide (CO_2) concentration. Depending on their mechanism of photosynthesis, certain types of plants are more sensitive than others to changes in atmospheric CO_2 concentration.

carbon finance. A branch of environmental finance that works on the premise that greenhouse gas emissions carry a monetary price. Through carbon finance, resources are provided to projects that generate (or are expected to generate) greenhouse gas (or carbon) emission reductions by way of purchasing such emission reductions at a price. The reductions in emissions are monitored and verified by an independent party. The selling of emission reductions has been shown to increase the bankability of projects, by adding an additional revenue stream in hard currency, which reduces the risks of commercial lending or grant finance. The World Bank has created the World Bank Carbon Finance Unit, which uses money contributed by governments and companies in member countries of the Organization for Economic Cooperation and Development to purchase project-based greenhouse gas emission reductions in developing countries and countries with economies in transition.

carbon intensity. The amount of emission of carbon dioxide per unit of gross domestic product.

carbon sequestration. The process by which *carbon sinks* (see definition) remove carbon dioxide from the atmosphere.

carbon sink. A reservoir of carbon that accumulates and stores carbon for an indefinite period. The main natural sinks are oceans and plants/algae (via photosynthesis).

climate change. Any change in climate over time, whether due to natural variability or as a result of human activity. This usage differs from that in the United Nations Framework Convention on Climate Change (UNFCCC), which defines climate change as "a change of climate which is attributed directly

or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods." See also *climate variability*.

climate prediction or **climate forecast.** The result of an attempt to produce a most likely description or estimate of the actual evolution of the climate in the future.

climate projection. A forecast of the response of the climate system to emission or concentration scenarios of greenhouse gases and aerosols, or radiative forcing scenarios, often based upon simulations by climate models. Climate projections differ from climate predictions in that they depend upon the emission, concentration, or radiative forcing scenario used, which are based on assumptions concerning, for example, future socioeconomic and technological developments that may or may not be realized and are therefore subject to substantial uncertainty.

climate variability. The variation in the mean state and other statistics (such as standard deviations and the occurrence of extremes) of the climate on all temporal and spatial scales beyond that of individual weather events. Variability may result from natural internal processes within the climate system (internal variability) or from variations in natural or human-induced external forcing (external variability) (IPCC 2001).

chikungunya fever. A disease caused by a virus that is transmitted to humans by virus-carrying *Aedes* mosquitoes. In humans, the virus causes an illness with symptoms similar to dengue fever. Symptoms include fever up to 39°C (102.2°F), severe pain in the joints of the extremities, rash of the trunk and occasionally the limbs, headache, conjunctival injection, and slight photophobia. The acute febrile phase of the illness lasts only two to five days; joint pain may persist for weeks or months.

coral bleaching. The paling in color that results if a *coral* loses its symbiotic, energy- providing, organisms.

coupling (also called **dependency**). The degree to which a program module relies on each one of the other modules that constitute the program.

development policy loans/operations. Loans available to borrowers from the International Bank for Reconstruction and Development (IBRD) and the International Development Association (IDA) who are not in arrears to the Bank Group. They are intended to provide rapid financial assistance to allow countries to deal with actual or anticipated development-financing requirements of domestic or external origins. They typically support the achievement of a set of development results through a medium-term program of policy and institutional actions consistent with a country's economic and sectoral policies. They can be stand-alone operations or, more frequently, be part of a programmatic series of operations. In programmatic operations, the Bank supports the implementation of a medium-term program of policy reforms through a series of annual operations, each of which is disbursed against a mutually agreed set of policy and institutional actions. Over fiscal years 2006 and 2007, IDA and IBRD development policy operations accounted for less than 30 percent of the World Bank's total financial commitments.

emission scenario. A plausible representation of the future development of emissions of greenhouse gases and aerosols based on a coherent and internally consistent set of assumptions about driving forces (such as demographic and socioeconomic development and technological change) and their key relationships. In 1992, the Intergovernmental Panel on Climate Change presented a set of emission scenarios that were used as a basis for the climate projections in the Second Assessment Report. These emission scenarios are referred to as the IS92 scenarios. For the Third Assessment Report (IPCC 2001) new

emission scenarios, namely the SRES scenarios (Special Report on Emission Scenarios of the IPCC), were published. These are known as the A1, A2, B1, and B2 family scenarios and were also utilized in the preparation of the Fourth Assessment Report (IPCC 2007a, 2007b, 2007c; final report in preparation). There are multiple variations of each family scenario.

energy intensity. The ratio of useful energy output of a system, conversion process, or activity to its energy input.

equivalent carbon dioxide (CO_2e). A measure for describing how much global warming a given type and amount of greenhouse gas may cause. Specifically, it is the *concentration* of CO_2 that would cause the same level of *radiative forcing* (see definition) as a given type and concentration of another type of greenhouse gas. It is expressed as parts per million by volume (ppmv). It provides an instantaneous measurement rather than one over time.

evapotranspiration. The combined process of evaporation from the Earth's surface and transpiration from vegetation.

extreme weather event. An event that is rare within its statistical reference distribution in a particular place. Definitions of "rare" vary, but an extreme weather event would normally be as rare as or rarer than the 10th or 90th percentile. By definition, the characteristics of what is called extreme weather may vary from place to place. An extreme climate event occurs when the same considerations apply to an average of a number of weather events over a certain period of time (e.g., rainfall over a season).

greenhouse gas. A gaseous constituent of the atmosphere that can be natural or made by humans. These gases absorb and emit radiation at specific wavelengths within the spectrum of thermal infrared radiation emitted by the Earth's surface, the atmosphere itself, and by clouds. This property causes the greenhouse effect. Water vapor (H_2O), carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4), and ozone (O_3) are the primary natural greenhouse gases in the Earth's atmosphere. Human-made greenhouse gases include halocarbons and other chlorine- and bromine-containing substances.

irrigation efficiency. The ratio between the estimated irrigation water requirements and the actual irrigation water withdrawal in a given location.

leishmaniasis. A disease caused by a parasite that is transmitted to humans by the bite of certain species of sand fly. The main symptoms are skin sores that erupt weeks to months after the person affected is bitten by sand flies. Likewise, fever, damage to the spleen and liver, and anaemia can also manifest themselves.

lymphatic filariasis. A disease caused by threadlike parasitic worms that are transmitted to humans by insect bites and lodge in the lymphatic system. The transmission agent is a certain type of mosquito. The main symptom is *elephantiasis*—the thickening of the skin and underlying tissues—that affects the lower extremities more commonly.

mitigation. Technological change and substitution that reduce resource inputs and emissions per unit of output. With respect to climate change, mitigation means implementing policies to reduce greenhouse gas emissions and enhance any process, activity, or mechanism meant to remove from the atmosphere such emissions, as well as aerosols and precursors of greenhouse gases.

morbidity. Rate of occurrence of disease or other health disorders within a population, taking account of the age-specific morbidity rates.

mortality. Rate of occurrence of death within a population.

ocean acidification. A decrease in the pH of sea water due to the uptake of anthropogenic carbon dioxide.

onchocerciasis. A disease transmitted to people through the bite of a black fly, which spreads parasitic worms *(Onchocerca volvulus)* throughout the body. When the worms die, they cause intense itching and a strong immune system response that can destroy nearby tissue, such as the eye. Thus, it is also known as "river blindness."

permafrost. Ground (soil or rock and included ice and organic material) that remains at or below 0°C (32°F) for at least two consecutive years.

radiative forcing. A measure of the influence a factor has in altering the balance of incoming and outgoing energy in the Earth-atmosphere system and an index of the importance of the factor as a potential climate change mechanism. In keeping with the IPCC's custom, in this report radiative forcing values are for changes relative to preindustrial conditions defined at the year 1750 and are expressed in watts per square meter (W/m^2) (from IPCC's *Climate Change 2001: Synthesis Report*).

risk (climate-related). The result of the interaction of physically defined hazards with the properties of the exposed systems in terms of their sensitivity or (social) vulnerability. Risk can also be considered as the combination of an event, its likelihood, and its consequences; that is, risk equals the probability of a climate hazard multiplied by a given system's vulnerability.

runoff. Surface flow occurring when the precipitation rate exceeds the infiltration rate of the soil or other surface material.

technical assistance (TA). A type of *analytical and advisory activity* (see definition) offered by the World Bank. Its main objective is to facilitate the transfer of skills and knowledge for developmental purposes. Technical assistance is a key instrument for improving policies and project design, enhancing skills, and strengthening implementation capacity.

transmission and distribution (T&D) losses. Energy losses that occur within any given power network due to poor maintenance, malfunction, or the use of inadequate devices (such as outdated transformers). The energy that escapes is wasted and not recovered. In South Asia, these losses are very high by international standards.

vector or **vector-borne disease (epidemiology).** A vector is an organism that transmits infection by conveying pathogens from one host to another but which does not cause disease itself. A classic example is the anopheles mosquito, which acts as a vector for the disease malaria by transmitting the malarial parasite *plasmodium* to humans. In this case, *plasmodium* is harmless to the mosquito (its intermediate host) but causes the disease malaria in humans (its definitive host).

white spot. An area where a lack of regional-scale data and information on climate, hydrology, and meteorology has hindered proper planning and decision-making.

zoonotic. A disease that normally exists in animals but that can infect humans.

Abbreviations

AOGCM	Atmosphere-ocean Global Circulation Model
CADF	Carbon Asset Development Fund
CBO	Community-based Organization
CDM	Clean Development Mechanism
CF	Carbon Finance
CFU	Carbon Finance Unit
CH_4	Methane
CNG	Compressed Natural Gas
CO_2	Carbon Dioxide
CO_2e	Equivalent Carbon Dioxide
CO_2eq	Carbon Dioxide Equivalent
CPF	Carbon Partnership Facility
CSO	Civil Society Organization
DPL	Development Policy Loan
DRM	Disaster Risk Management
DSM	Demand-side Management
ENSO	El Niño Southern Oscillation
EU	European Union
GDP	Gross Domestic Product
GEF	Global Environment Facility
GFDRR	Global Facility for Disaster Reduction and Recovery
GHG	Greenhouse Gas
GIS	Geographic Information System
GLOF	Glacial Lake Outburst Flood
IBRD	International Bank for Reconstruction and Development
IDA	International Development Association
IFC	International Finance Corporation
IPCC	Intergovernmental Panel on Climate Change

JI	Joint Implementation
kgoe	kilograms of oil equivalent
LDCF	Least Developed Countries Fund
MDG	Millennium Development Goal
NAPA	National Adaptation Program of Action
NGO	Non-governmental Organization
N_2O	Nitrous Oxide
OECD	Organisation for Economic Co-operation and Development
ppm	parts per million
PPP	Purchasing Power Parity
SCCF	Special Climate Change Fund
SAR	South Asia Region
SHG	Self-help Group
SPA	Strategic Priority on Adaptation
SRES	Special Report on Emissions Scenarios
TA	Technical Assistance
T&D	Transmission and Distribution
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
VKT	Vehicle-kilometers of Travel

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Executive Summary

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The Global Challenge

The world is facing a prolonged period of planetary surface warming that is unparalleled in human history. The scientific consensus holds that this is largely a consequence of human-generated emissions of greenhouse gases (GHG). The 1990s were the warmest decade and 2005 the warmest year on record since 1800. The impacts of higher temperatures are already being felt and are visible in melting of some glaciers, rising sea levels, more frequent storms, and extreme weather events. At current trends, scientists predict that the Arctic could be free of ice within 100 years.

Climate change has become central to the development and poverty-reduction agenda. Progress toward attaining many development goals, such as eradicating poverty, combating communicable diseases, and ensuring environmental sustainability, could be made more challenging. The effects of global warming are likely very unfair. Industrialized countries are responsible for the vast bulk of past and current greenhouse gas emissions. However, the developing countries and the poorest people will suffer the most from climate change because of unfavorable geography, limited assets, and a greater dependence on climate-sensitive sources of income. Yet few developing countries are well adapted to even current climate variations. Climate change is predicted to increase the variability and frequency of extreme events in ways that are outside the realm of experience. Some of the impacts are predicted to be in the form of new challenges (such as glacier melt and sea-level rise) and others as age-old threats made more severe by climate change (such as flooding or drought).

Background and Approach

***South Asia: Shared Views on Development and Climate Change* builds upon the World Bank Group's *Strategic Framework for Development and Climate Change (Framework),* which defines the pillars and priorities of the climate challenge.** Within the context of the global *Framework*, this document identifies the climate challenges in South Asia. It outlines the broad parameters of a response that is consistent with the development priorities of the region. The main aim is to help South Asian countries begin a process that would build climate-resilient economies that grow along a low-carbon trajectory. Adaptation to climate change lies at the heart of such a climate response, 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. This document emphasizes the need for approaches that are aligned with country priorities and attempts to inform and support country programs by deepening knowledge of the climate-change challenge to development, expanding the policy toolkit to address climate challenges, and facilitating access to additional financial resources. The focus is on the consequences of climate change on economic growth, poverty reduction, and achieving the Millennium Development Goals (MDGs). The approach has been informed and developed through very extensive consultations in the region that took numerous forms: meetings, physical and virtual, workshops, conferences, and Web-based interactions. These interactions occurred over a seven-month period with governments, development partners, think-tanks, nongovernmental organizations, and individuals. There were several thousand downloads of the document from the Bank's website and a correspondingly high number of comments received from readers and experts in the region.

Climate policies in South Asia will need to be tailored to risks and country circumstances. South Asia's climate is as diverse as its landscape. The region spans a variety of climate zones, including arid deserts, parched rangelands, freezing alpine mountains, and humid tropical islands. The projected impacts of climate change will be heterogeneous, suggesting that there can be no one-size-fits-all approach to building climate resilience across South Asia. Responses will need to be customized to specific risks and circumstances.

Why is South Asia so Vulnerable to Climate Change?

Geography coupled with high levels of poverty and population density has rendered South Asia especially vulnerable to the impacts of climate change. The region faces daunting climate-related development challenges. High population levels translate into increased resource demands on an already stressed and largely degraded natural resource base. With an estimated 600 million people subsisting on less than US$1.25 per person a day, even small climate variations can cause irreversible losses and tip a large number of people into destitution.

The region is highly susceptible to natural disasters. Over 50 percent of South Asians—more than 750 million people—have been affected by at least one natural disaster in the past two decades. The human and economic toll has been high, with almost 230,000 deaths and about US$45 billion in damages. The region shares common geological formations and river basins, so that natural hazards frequently transcend national boundaries. With climate change the frequency and incidence of such natural disasters is projected to increase.

Compounding these risks is the region's heavy reliance on the monsoon. The monsoon is the most significant climate event in the region's economic calendar. It carries over 70 percent of South Asia's annual precipitation in a brief four-month period.[2] A buoyant monsoon heralds bountiful harvests and financial security, yet when the monsoons fail, or are excessive, suffering and economic loss are widespread. If climate projections are indicative of future trends, the risks associated with water-related climate variability are likely to worsen.

The retreating of some glaciers in the Himalayas could present the most far-reaching challenge to the region. The Himalayas are a vital life-sustaining resource for South Asia. The Himalayan ecosystem supports some 1.5 billion people who live directly in the floodplains of its many rivers (e.g., Indus, Ganges, Brahmaputra, and Meghna). The Himalayan system influences monsoon dynamics,

[2] Most of the region relies on the summer monsoon, which runs from June to September. In Sri Lanka and the Maldives, however, it is the winter northeast monsoon that delivers most of the precipitation, between November and January.

acts as a natural reservoir to sustain crops, provides groundwater recharge, and is home to a unique ecosystem with an abundance of endemic species. But with rising temperatures the ice mass of the Himalayas and Hindu Kush is retreating more rapidly than the global average. This poses an unprecedented threat to water supplies, lives, and the economies of the region. The retreating of some glaciers illustrate the interconnectedness of South Asia.[3] With melting glaciers, flood risks would increase in the near future. In the long term, there can be no replacement for the water provided by glaciers, which could result in water shortages at an unparalleled scale. Agriculture and the region's economic structure will need to undergo significant adjustment to cope with these changes.

Sea-level rise is a further concern. The region has long and densely populated coastlines with many low-lying islands. In the severe climate-change scenarios,[4] sea-level rise could pose an existential threat, potentially submerging much of the Maldives and inundating 18 percent of Bangladesh's total land, directly impacting 11 percent of the country's population. Saltwater intrusion from sea-level rise in low-lying agricultural plains could lead to food insecurity, further increase the prevalence of water-related diseases, and reduce freshwater supplies. Many of the region's primary cities (e.g., Chennai, Cochin, Karachi, Kolkata, and Mumbai)—the engines of regional growth—are located on the coast and threatened by sea-level rise. The immediate impact of sea-level rise is on coastal communities and ecosystems. Ripple effects could be felt beyond borders if there is large-scale displacement of populations in densely inhabited coastal areas and erosion of protective coastal ecosystems.

Many of the most severe impacts of climate change are likely to be regional and will call for coordinated regional responses. Bangladesh shares 54 rivers with India. Changes in upstream runoff and demand due to climate change could significantly impact future water availability across all these rivers. Likewise, sea-level rise could displace much of the population along the coastal zone and induce cross-border migration. Climate-sensitive diseases could spread rapidly across borders in a globalized world. The past decade saw dengue fever, cholera, and Rift Valley fever spread across and between continents. Adaptation to climate change might therefore require not just local action but also cross-boundary cooperative arrangements. Partnerships and coordinated approaches provide a cost-effective way of adapting to the impending regional climate related risks.

The cascading effects of more variable rainfall and higher temperatures could impact most aspects of life and the economy. Weather extremes and greater fluctuations in rainfall have the capacity to refashion the region's comparative advantage. Food security, health, livelihoods, and access to basic services of water, sanitation, energy, and shelter could all be compromised. Expected impacts of climate change include the following:

- Reduction of yields of major crops by as much as 20 percent and an even sharper decline in

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[3] Evidence also suggests that climate change in China is influencing glaciers across the entire Himalayan range.

[4] Reference here is to the Intergovernmental Panel on Climate Change (IPCC) A2 scenario.

agricultural incomes in the worst-case climate scenarios.

- Growing scarcity of water, with a need to balance more variable water supplies with the accelerating demand for water.
- Economic losses and damage to high-value infrastructure, particularly in the vulnerable coastal cities.
- Irreversible loss of ecosystems and ecological services, particularly in fragile and unique biomes covering terrestrial and marine ecosystems (such as the Himalayas, the Western Ghat biosphere encompassing India and Sri Lanka, and the fragmented coral reefs). In sum, high population densities, a large concentration of poverty, and the region's climate variability have all combined to make South Asia especially vulnerable to the consequences of climate change. Climate change has the potential to compound existing development problems and increase pressures on key resources needed to sustain future growth, urbanization, and industrialization.

South Asia's Greenhouse Gas Contribution

The region has recently emerged as a significant contributor to greenhouse gas emissions. High economic growth has fueled a growing and insatiable thirst for energy in South Asia. Rising energy demand is driven by urbanization, industrialization, and prosperity, all of which are part of a broader process of development that is lifting millions of South Asians out of poverty. Increased energy consumption has been accompanied by rising greenhouse gas emissions. On average, emissions have risen at about 3.3 percent annually in the region since 1990—more rapidly than in any other region except the Middle East. Total emissions exceed 2.5 $GtCO_2eq$ (billion metric tons of carbon dioxide equivalent). However, per capita emissions of the region are still extremely low by international standards—less than one-fifth of the developed countries.

As the region strives to meet its development goals, the potential for further growth in emissions is enormous and driven by basic needs. Over 500 million people in South Asia have no access to electricity. How the region meets the legitimate demands for energy and economic prosperity will have far-reaching consequences on global greenhouse gas emissions. Growth typically spurs emissions in rough proportion to the income it generates.[5] Hence, South Asia, like the rest of the world, faces an enormous challenge to sustain its growth while addressing global warming.

Coal is the backbone of the energy sector and would likely remain the dominant fuel that will power much of South Asia. India has the third-largest stock of proven coal reserves in the world, after the United States and China. Strategies to lower emissions by diversifying into cleaner sources of power are constrained by energy resources. India, the largest energy consumer in the region, is not well endowed with reserves of cleaner fuels such as oil, gas, and uranium.[6] Hydropower potential is significant and large in absolute terms (150,000 megawatts) but small compared to the country's future energy needs.[7] There are considerable and untapped possibilities for importing hydropower from Nepal and Bhutan and wind power from Sri Lanka, but there remain difficulties in establishing transboundary energy trade agreements. Because of the cost advantage of coal at the oil prices that have prevailed in recent decades, Bangladesh,

[5] Globally, a 1 percent increase in per capita income has induced, on average, a 1 percent increase in greenhouse gas emissions.

[6] In 2005–6 oil reserves were estimated at 786 metric tons and gas reserves are 1,101 million cubic meters (Government of India, Planning Commission 2006).

[7] According to the Government of India's Integrated Energy Policy (2006), with 8 percent growth, 150,000 megawatts of hydropower would supply about 5 percent of total energy needs in the best case scenarios by 2030.

Pakistan, and Sri Lanka will increasingly find coal emerging as the front-runner for incremental power generation. Cleaner coal technologies are likely to play a pivotal role in addressing the global climate challenge at least in the short term.

There are large gains to be had from promoting energy efficiency and reducing power losses. Much of the industrial output in the region is from small- and medium-scale enterprises that utilize outdated and inefficient technologies and processes. Cost-effective energy-efficiency opportunities exist across the entire chain of energy production, distribution, and consumption in all South Asian countries. In addition there is scope for reducing emissions from existing thermal power plants. Many of the plants in the region are aged, inefficient, and highly polluting. Rehabilitation of these with cleaner technology can generate substantial emission reductions. Such measures would be in line with the countries' needs for more energy to sustain their growth as well as with global mitigation objectives.

Cities are major contributors to greenhouse gas emissions. Rapid urbanization has been accompanied by increased demands for transportation, energy, water supply, sanitation, and increased generation of wastewater and solid waste, all of which contribute to greenhouse gas emissions. Fortunately there remain large and untapped opportunities for South Asia to simultaneously improve services (waste treatment, public transport, etc.) and quality of life while reducing the greenhouse gas footprint of the urban landscape.

Agriculture is also a major contributor to greenhouse gases. Rice and livestock are the primary sources of agricultural emissions and account for more than 20 percent of emissions from South Asia. However, the per-hectare emissions from rice in South Asia are lower than the global average, reflecting the special features of the agricultural landscape: poor soils, low levels of chemical application, and planting regimes in the region. In addition in some countries a significant proportion of underpriced electricity is used for groundwater extraction and lift irrigation. There appears to be limited potential to substantially lower agricultural emissions. Much of the livestock herd subsists on common pastures with little scope for altering diets in ways that can lower methane emissions. Likewise, with low per-acre emissions from paddies, opportunities for substantive reductions from rice emissions are also restricted.

Michael Foley/World Bank

Broad Principles of a Development Approach for Climate Change

Effective adaptation poses significant policy challenges. Countries need to devise responses in the face of uncertainties on the timing, location, and severity of climate impacts. The scale of these impacts will be contingent upon global mitigation efforts undertaken in the next few decades. Delayed or limited emission stabilization will necessitate considerably greater investment in risk management and adaptation. These uncertainties need to be factored into the development of adaptation strategies and financing plans. The policies and institutions that enable South Asian countries to cope with these risks today will build

resilience in addressing future risks. Climate change is also predicted to bring new and unprecedented problems, such as those associated with sea-level rise and melting of some glaciers. This will call for building new policies to prepare for the potential adverse impacts. However, given 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 to adequately respond to the challenge of climate change. In many cases, institutions will be considerably challenged by the crisis of climate change, in particular where structures and responsibilities are fragmented and technical capacity is limited.

To promote climate-resilient development and growth in South Asia, there is broad recognition that adaptation activities will need to be guided by five pillars:

- **A "no-regrets" approach:** No-regrets approaches build resilience to climate risks and also generate co-benefits.[8] Faced with uncertainty about future climate outcomes, no-regrets policies provide a mechanism for hedging against future climate risks. Irrigation, health care, infrastructure, agriculture technology, disaster preparedness, habitat protection, and equitable and environmentally sensitive growth lend themselves to no-regrets interventions. These simultaneously deliver climate resilience and current development benefits.

- **A focus on the poor:** The most vulnerable are the poor in the developing countries. They have limited resources, and their assets and livelihoods are tied to climate-sensitive factors of production. Building the resilience of these groups to current climate risks would generate immediate development dividends and reduce future climate vulnerability.

- **Investment in knowledge:** Climate science is imperfect, and it is not possible to predict with certainty the path of future climate risks and the likely damages. Under uncertainty, knowledge has high value, and this will require vigorous investment in generating information and building awareness in the relevant policy agencies.

- **Regional cooperation:** The most severe climate threats (such as glacier retreat and sea-level rise) transcend national boundaries. Likewise, in an increasingly globalized world, climate-sensitive diseases spread rapidly beyond their origins. Finding effective solutions will require cooperation between countries to jointly address shared problems.

- **Maintaining the integrity of environmental services:** Recognizing that climate change is a consequence of damaged and diminished eco-services, the remedial measures need to be aimed at protecting and restoring ecosystem integrity. Indeed, maintaining ecosystem integrity can provide a cost-effective way of building climate resilience and a buffer against climate impacts.[9]

With a large proportion of South Asia's population living below the poverty line, any low-carbon growth initiative must be consistent with the development objectives of improving living standards and incomes. This is the principle that guides the Bank's programs. Fortunately, opportunities do exist to harness win-win outcomes by focusing on measures that generate significant co-benefits, such as improvements in

[8] A no-regrets policy is one in which the benefits are not highly contingent upon a particular climate change outcome and would accrue across a broad range of climate scenarios (including the status quo).

[9] Through much of South Asia the diversion of forest land in protected areas to other uses is typically not sanctioned. Bhutan remains the exemplar in terms of the stewardship of its habitat and as consequence the high productivity of its natural capital. Notable too has been the recent reaffirmation by the Minister of Environment and Forests that protected areas in India are not to be converted to other uses.

energy and economic efficiency, reduction in local pollutants, and improvements in natural resource management. The South Asia region has initiated a strong dialogue and a work program that includes knowledge sharing and investments to realize these multiple benefits.

Recognizing the need for approaches to be informed and led by country development priorities, there are three key pillars that guide the low-carbon development and growth agenda:

- **Win-win policies:** Such policies not only provide global benefits in reducing greenhouse gases but also pay for themselves in local benefits, such as reduced fuel expenditure, improved air quality, and natural resource management.
- **Support for low-carbon growth activities:** South Asian countries would need to be compensated for the additional costs of mitigation actions that go beyond their development objectives. This approach underlies the United Nations Framework Convention on Climate Change (UNFCCC) principle of "common but differentiated responsibilities." This convention recognizes that current climate risks are the consequence of past actions by developed countries and that low carbon investments must not detract from current development imperatives.
- **Accelerated technology deployment:** Promoting research and the wider adoption of emerging clean technologies would result in a number of benefits.. Developing new technologies is expensive and risky, but with continued research and early adoption they can become more economical and accessible. Developing countries, however, do not have the resources necessary to undertake unproven, risky technological research. Development, deployment, and diffusion of new technology are critical to enabling developing countries to meet the challenges of climate change. Technology transfer by the developed countries is necessary to achieve the goal of balancing growth and adoption of clean energy sources. The Bank can play a supportive and catalytic role in this process.

Most South Asian countries already spend a significant proportion of their development budgets on disaster relief and programs that address climate-related risks to welfare and development: Investments in disaster prevention and management plays a minor role in comparison to disaster relief, however. Climate change is likely to increase the frequency of adverse climate events in ways that are outside the realm of current experience and could compromise the effectiveness of development efforts in climate-sensitive sectors of the economy.

World Bank's Role

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. Much of the Bank's current portfolio of activities in South Asia is already structured to promote growth under climate constraints. The adaptation dimension is closely linked to the Bank's core development mission and includes a well-targeted package of interventions aimed at reducing exposure to climate risks, promoting integrated coastal zone management, and building climate-resilient rural economies. There is also a growing engagement in

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understanding and addressing the risks in the large coastal cities of South Asia, which generate much of the region's investment and growth but where climate vulnerabilities are high. The Bank's energy portfolio in the region has been moving toward promoting energy efficiency, renewable energy, and institutional reforms aimed at improving energy service and efficiency. The approach envisions that the Bank will continue to play a key role in facilitating South Asia's transition to a low-carbon-growth trajectory and promoting climate-resilient development.

Building country ownership, capacity, and awareness is the key to tackling the climate-change problem. The global funds available for addressing climate change are limited. So expanding the many climate-friendly interventions in the Bank's portfolio will not be sufficient to tackle the climate challenge in South Asia. The solution to leveraging limited resources effectively lies in promoting country ownership of climate-change issues. This calls for selectivity with a focus on outcomes that build institutional capacity and deepen knowledge so that climate-change risks are incorporated in country development policies, plans, and programs. It also requires high-impact investments that could have catalytic effects.

Toward a Sustainable Development Trajectory in a World with Increasing Climate Change

The Bank is one of many players in the global arena of climate change. The Bank's comparative advantage is to help countries address the highly likely impacts of climate change across its many development challenges—local, national, and regional. To this effect, the Bank could use an array of instruments that will lead to a shift in the services that it provides to its clients as they strive for development and poverty reduction while building climate resilient and low-carbon trajectories. Depending on the various clients' demands and priorities, the Bank could offer the following:

- **Climate-specific investments:** The new climate funds such as the Climate Investment Funds, Global Environment Facility climate funds, and carbon-finance programs provide the additional resources that are required for climate-specific activities for both adaptation and low carbon growth.

- **Integration of climate considerations in the portfolio:** With client countries spending large sums of money on investments, there is a need to ensure that they get the most sustainable long-term outcomes possible. This includes the consideration of likely climate-change impacts, e.g. on infrastructure, on ecosystems, and on services such as water supply or health care. The Bank will include climate-change considerations in its investments in order to help clients build climate resilience and low-carbon trajectories in the investments that would be undertaken anyway, and whose quality would be compromised if climate considerations were neglected.

- **Technical assistance for knowledge, research, and capacity building:** With uncertainty of likely climate impacts, there is a clear need to fill critical knowledge gaps in

ways to raise awareness that could improve decision making. The Bank has already played an important role with contributions on adaptation to climate change in climate-stressed areas and a low-carbon-growth study for India. But much more remains to be done to better understand highly likely critical climate risks and their economic impacts across the region, as well as to identify low carbon growth opportunities. Climate change will also challenge existing institutional structures and calls for greater integration of likely risks in development policy, as well as cross-sectoral coordination among various government agencies. Technical assistance would need to play a key role for building institutional capacities and defining the architecture for improved climate governance. With its presence across all countries in South Asia, the Bank can play an especially useful role in catalyzing a regional dialog on the common climate risks and opportunities.

- **Financing and harmonization:** In an environment of resource scarcity there, is a need to utilize existing resources effectively, which calls for, among other things, harmonization with other development partners. The Bank can play a key role in helping countries leverage existing global resources more effectively and coordinate with development partners. The Bank is also a significant player in developing alternative financial modalities and instruments. Climate-specific multidonor trust funds, innovative instruments for risk financing (such as catastrophe (CAT) bonds and climate contingent insurance), and "green" bonds are among the many initiatives under various stages of development and application.

This approach is based on the premise that flexibility is needed to update and adjust responses as knowledge regarding likely climate-change effects improves and as the economies of South Asia grow. It is expected that instruments will evolve and be adjusted, in ways that allow the Bank to help countries cope with an evolving situation. The ultimate aim is to support the development objectives of South Asian countries in a world with increasing climate change.

Table E.1 provides a summary of the main climate risks that have been identified in the region, based on documents of the Intergovernmental Panel on Climate Change (IPCC), National Communications, National Adaptation Action Plans (where available), and other related peer-reviewed sources.[10] Table E.2 outlines the priority responses across the South Asia region. The risks and responses imply the need for a more climate-sensitive approach to development.

[10] The summary is based on a subjective and qualitative assessment of the literature.

Table E.1 Summary of Climate Risks by Country

	Afghanistan	Bangladesh	Bhutan	India	Maldives	Nepal	Pakistan	Sri Lanka
Sea-level rise	–	√	–	√	√	–	√	√
Glacier retreat	√	√	√	√	–	√	√	–
Temperature increase	√	√	√	√	√	√	√	√
Floods more frequent	?	√	√	√	√	√	√	?
Drought more frequent	√	√ (some areas)	?	√	–	?	√	?

Likely: √ Not Present: – Unknown: ?

Table E.2 Summary of Regional and Sector Impacts in the Context of Climate Change and Priority Responses

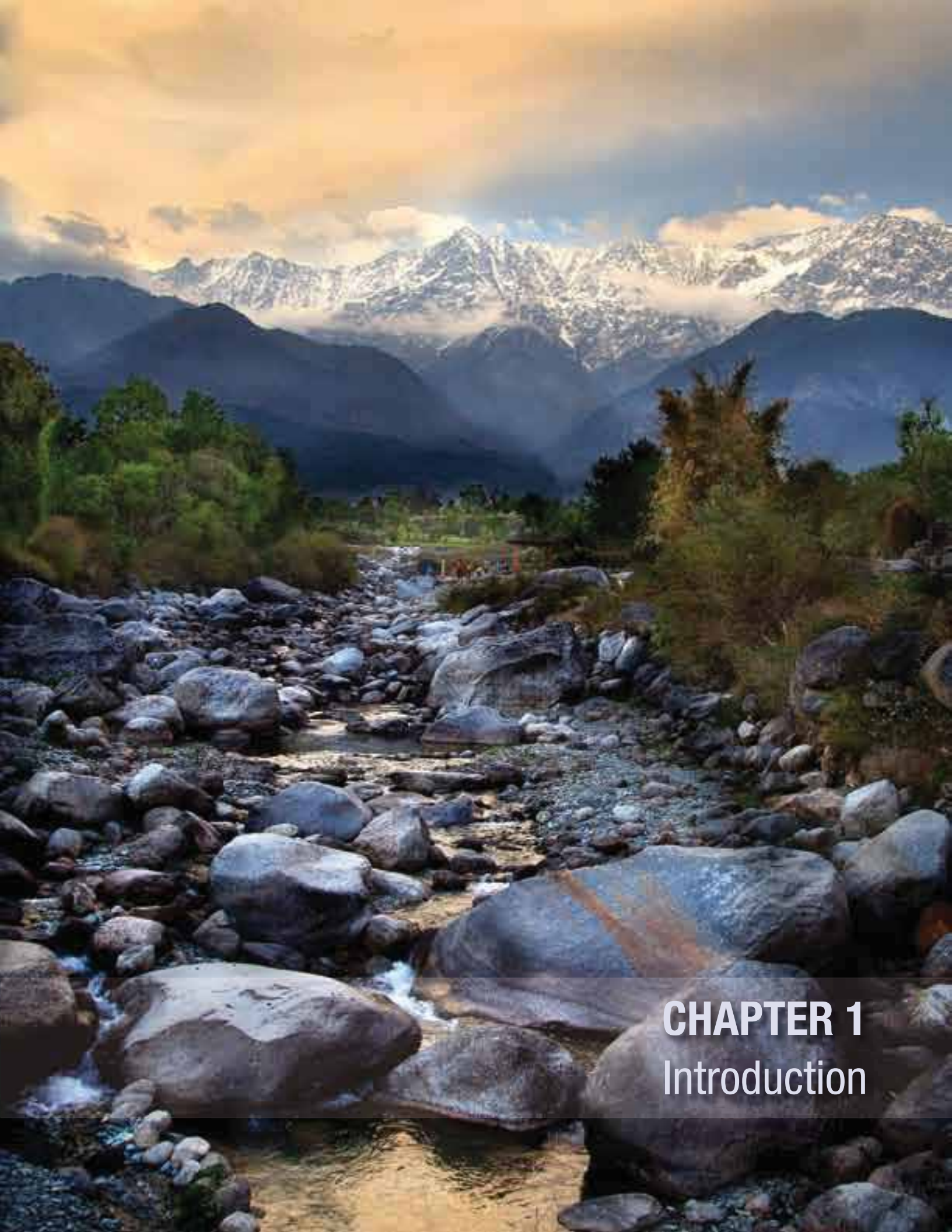
Sectors	Risks	Priority Response
Regional and Cross-sectoral	• Information gaps • Limited coordination between sectors and countries • Funding gaps for both adaptation and low-carbon growth	• Knowledge products • Institutional coordination and strengthening • Resource mobilization
Water	• Melting of some glaciers 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.
Agriculture	• Declining yields of major crops • Agriculture unviable in marginal areas e.g. arid, semi-arid, and coastal (saline intrusion-affected 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, contingent credit schemes) • Irrigation development and increased investment in in water harvesting

Sectors	Risks	Priority Response
		infrastructure at required scales that take account of climate risks • Development of incentives and innovative approaches for rural development to diversify income and buttress against climatic risks
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 nonstructural measures • Catastrophe risk financing or transfers (where needed)
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
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, indigenous populations IPs and other vulnerable groups for reducing agricultural dependence • Promotion of self-help groups (SHGs); and enhancing of access to microfinance and banking services • Strengthening social capital of vulnerable groups, their access and decision making • Promotion of community-based asset building and sharing of natural resources
Ecosystems and Biodiversity	• Quantitative and qualitative damage upon 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, climate mitigation, adaptation and risk management • Designing and building biodiversity-friendly and climate-resilient infrastructure • Generation of knowledge and capacity

Sectors	Risks	Priority Response
Energy	• Political economy (nonclimate) barriers to developing regional energy trade • Poor quality local coal • Aging and inefficient thermal power generation, high transmission, and distribution losses • Inefficient energy use • Poor energy pricing frameworks including underpriced electricity for lift irrigation, which can consume up to 20 percent of supplies in some countries	• 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 • Harnessing of hydropower potential • Energy efficiency and reduction of system losses • Investment in (nonpolluting) renewable energy
Transport	• Increase in number of private vehicles and usage per vehicle • Increase in age and efficiency of vehicle fleet • Ongoing deterioration of public transport in cities • Expansion of low-density urban land development which is not friendly to public transport and nonmotorized transport • Rail freight competitiveness and efficiency	• 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 • Promoting the modal shift to rail transport • Fuel efficiency standards for road vehicles
Urban	• Climate-related damage upon 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 mitigation potential in industries such as solid waste, wastewater treatment, energy-efficient buildings and infrastructure • Improving energy-efficient buildings

PART I

General Context and Strategic Responses



CHAPTER 1
Introduction

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Introduction

The Context

A broad scientific consensus holds that climate change is already occurring and is bound to continue, even under the most optimistic scenarios. The current pace of change in the world's climate is unprecedented in recent human history. 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. Although crucial mitigation of greenhouse gas emissions can help to alter dramatic long-term impacts, most of the changes projected for the coming decades can no longer be avoided. Climate change is a problem that the world will have to confront.

Addressing climate change presents a daunting policy problem. At the most fundamental level, climate change is a global issue, necessitating an international response. However, there are both temporal and spatial inequities in tackling the climate challenge. Not all countries are equally affected; nor do they all have an equal capacity to respond. Developing countries, and particularly the poorest among these, are most vulnerable, with likely impacts that would implicate crucial development needs and food-security goals. More problematic is that the benefits of addressing the problem accrue in the uncertain and distant future, while the costs weigh upon current generations. Collectively these features create unrivaled challenges of unmatched complexity.

Recognizing the risks to development from climate change, the World Bank (the Bank) has recently articulated a *Strategic Framework for Development and Climate Change (Framework)* (World Bank 2008a). The *Framework* views climate change through a development prism with an emphasis on growth and poverty reduction and defines the Bank's overarching response to the development challenge under climate constraints (Box 1.1). This

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document builds upon the *Framework* and identifies the guiding principles to address the challenges of climate change in South Asia. It is based on a consultative approach that identifies the common principles and understanding that is emerging. There is growing recognition that vulnerability to the likely impacts of climate change is high in South Asia, where there are urgent development priorities. There is therefore a need for responses to be calibrated to government priorities and socioeconomic conditions in the region.

Within the context of the global *Framework* this document identifies the climate challenges within South Asia. It outlines the broad parameters of a response that is consistent with the development priorities of the region. The main aim is to help South Asian countries begin a process that would build climate-resilient economies that grow along a low-carbon trajectory. Adaptation to climate change lies at the heart of such a climate response, 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. This document emphasizes the need for approaches that are aligned with country priorities and attempts to inform and support country programs by deepening knowledge of the climate-change challenge to development, expanding the policy toolkit to address climate challenges, and facilitating access to additional financial resources. The focus is on the consequences of climate change on economic growth, poverty reduction and achieving the Millennium Development Goals (MDGs).

Report Structure

The document has two parts. **Part I** defines the broad parameters, directions, and principles for addressing the climate-change challenge in South Asia. It begins with an assessment of the global dimension of the problem. It then identifies the broad likely impacts of climate change in South Asia and the region's recent contribution to the problem. It outlines the reasons why the region is highly vulnerable to the likely impacts of climate change and the key principles that would guide a response to the climate challenge in ways that are sensitive to country needs. Many of the far-reaching climate impacts are projected to cut across sectors and national boundaries, necessitating regional approaches with integrated responses. The annex provides a snapshot of likely climate impacts in South Asian countries.

Reflecting the multisector scope of the challenge, the **Part II** provides a detailed assessment of the potential risks and responses in sectors where climate risks and consequences are high: water resources, agriculture, energy, transport, the urban space, biodiversity, and the social sphere. The links are often complex and interconnected and run both ways; many sectors are threatened by climate change and also have an impact on future climate outcomes. Likewise, climate impacts in one sector, such as water availability, can have cascading effects in other segments of

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Box 1.1 The Strategic Framework on Development and Climate Change

The *Strategic Framework on Development and Climate Change* defines the World Bank Group response to the development impacts of climate change. It identifies six broad priority actions for both adaptation and mitigation:

- Support climate actions in country-led development processes
- Mobilize concessional finance
- Facilitate the development of market-based financing mechanisms
- Leverage private sector resources
- Support accelerated development of new technology
- Increase policy research, capacity building, and knowledge

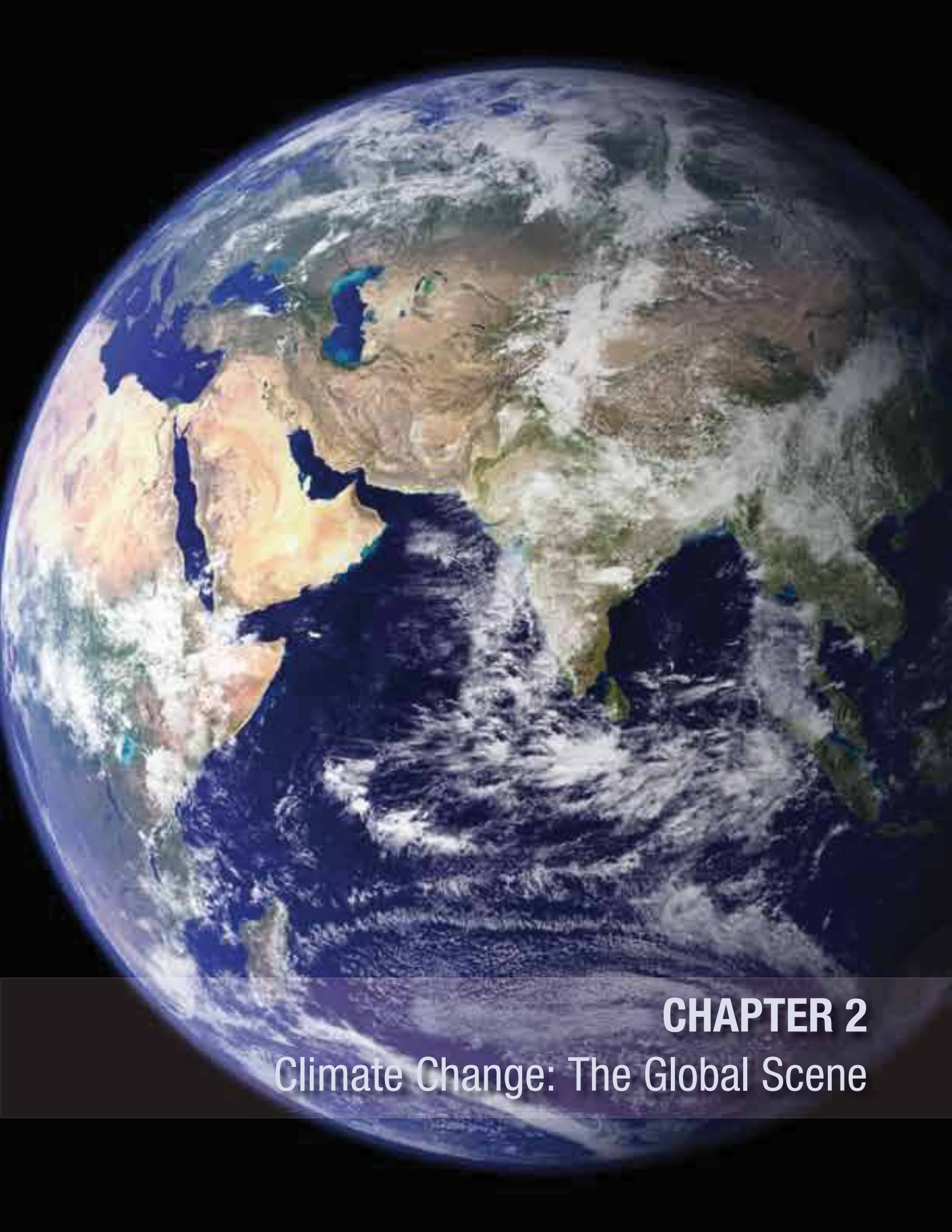
Source: World Bank 2008a

the economy, such as agriculture and industry. A common theme that emerges is the need for better information and knowledge of these links to define well-articulated responses to the climate challenge.

Process and Consultation

This document is the product of extensive consultation and intensive collaboration with inputs from all sectors in the South Asia Region of the Bank and many networks. This structure has encouraged an effective exchange of information that has promoted learning and the integration of climate issues in sectoral programs. The document has also benefited from consultations held in Bangladesh, India, and Sri Lanka for the *Strategic Framework for Development and Climate Change*. It incorporates the views and concerns of the many stakeholders that emerged during these discussions.

Following a management review of an initial draft document, a wide country and Web-based consultation process has been undertaken. There have been multi-stakeholder consultations and workshops in Bangladesh, India, and Nepal, as well as consultations with governments. The themes enunciated here were central to the first regional climate-change conference in South Asia. "From Kathmandu to Copenhagen," hosted by the Government of Nepal in Kathmandu in September 2009. To ensure broader outreach across a range of constituencies, the document has been posted on the website. There have been more than 7,000 downloads from the Bank's website and comments that cover the full spectrum of views on climate change. The approach outlined in this document reflects a wide chorus of opinion that asserts that in South Asia the development impacts of climate change are of the greatest importance.



CHAPTER 2
Climate Change: The Global Scene

CHAPTER 2
Climate Change: The Global Scene

This chapter begins with a brief overview of the problem, the scientific underpinnings, the certainties and uncertainties, and the likely effects of future climate change. It describes what climate change means, why it matters, and why it is not strictly an environmental issue, but is also a crucial development concern. It then outlines the contribution of sectors and countries to greenhouse gas emissions and the various approaches for stabilizing emissions.

The Science of Climate Change

Is there Evidence of Climate Change?

The Earth is warming and its climate is changing. Indeed, measurements show that the Earth has warmed by 0.74ºC over the past 100 years. Warmer surface temperatures heat the oceans, melt ice sheets, and alter weather patterns across the globe. As a result, sea levels have risen globally by 10–20 millimeters during the 20th century and snow cover has receded by about 10 percent since the 1960s, with a 5-kilometer retreat in the alpine and continental glaciers. In the Arctic, where the expanding ocean absorbs more heat, the ice cover has retreated faster than the global average. If this melting continues, science predicts that summers in the Arctic will be ice free within 100 years.

Climate change is about more than just rising temperatures. There are cascading effects, with such areas as the Sahel, the Mediterranean Basin, Southern Africa, and parts of Southern Asia becoming drier due to more heat and evaporation. Other areas are experiencing increased and more variable precipitation, particularly the east of North and South America, Northern Europe, and Northern and Central Asia. Over the past 50 years, weather patterns have also become more variable. Storm duration and peak winds of tropical cyclones have increased, together with ocean warming. These impacts do not register as apocalyptic events. However, increased exposure to droughts, floods, and environmental stress are beginning to take their toll on communities in climate-vulnerable parts of the world. In South Asia, the projected impacts of higher temperatures, more variable precipitation, more extreme weather events, and sea-level rise will likely continue to intensify. These changes would have the greatest impacts on the lives and livelihoods of millions of poor people who remain exposed to climate risks. This is the subject of subsequent chapters.

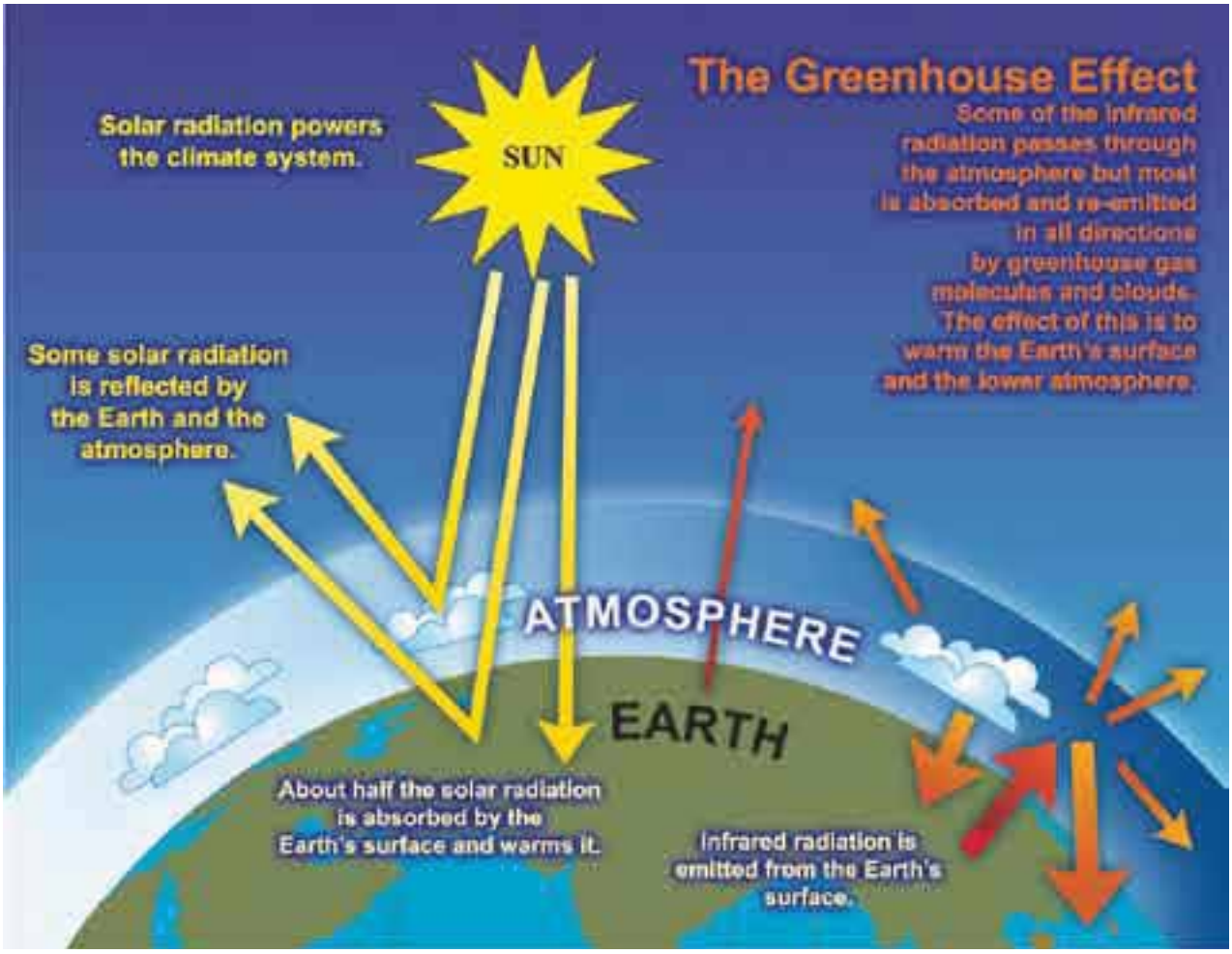
Why is the Climate Changing?

The scientific understanding of climate change is now sufficiently clear. The causes of global warming,

the extent of climate change, humanity's contribution to it, and the consequences for development have all been vigorously disputed. The broad science has now settled and with rare unanimity a broad scientific consensus holds that climate change is a consequence of human activities. Carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (NO_2) are the main greenhouse gases (GHGs) that are produced through human activities, primarily the burning of fossil fuels and deforestation. These GHGs trap heat inside the atmosphere and warm the surface of the Earth (see Box 2.1).

Box 2.1 What is the Greenhouse Effect?

The composition of the atmosphere is important in determining the Earth's climate because 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 below). Life on Earth is made possible because of this effect, which maintains the global mean surface air temperature at around 15°C (59°F). As the volume of these "greenhouse gases" increases, so too does the Earth's temperature. Temperature changes in turn alter climate systems. A complex feedback loop may emerge whereby a change in one factor, such as temperature, changes another factor, such as the volume of water vapor, which either reinforces or offsets the initial temperature change. A substantial part of the uncertainty in projecting future climate change is due to an incomplete understanding of these feedback processes.



Source: IPCC 2007a (reprinted with permission)

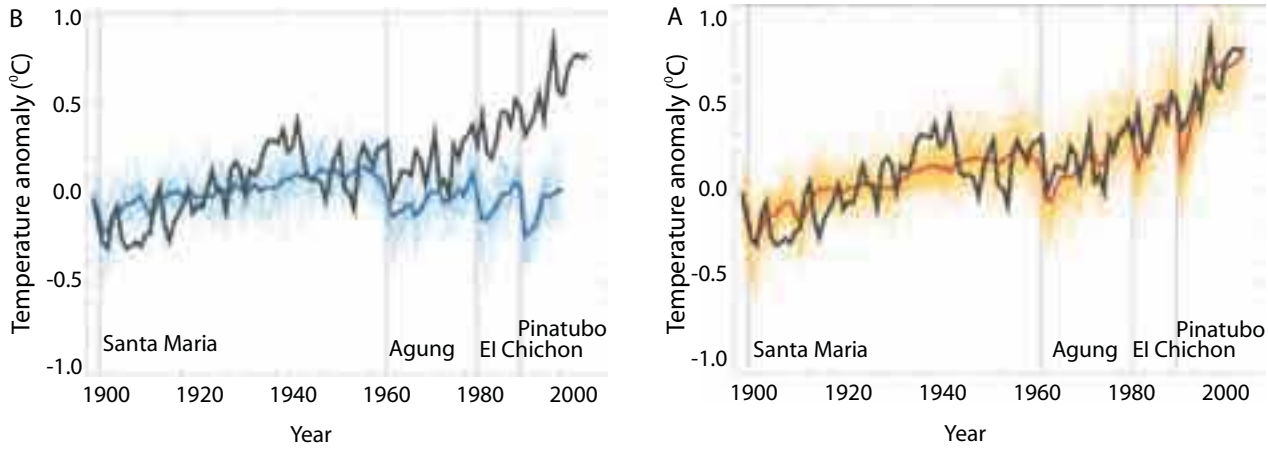
In a natural equilibrium the amount of CO_2 released in the atmosphere is in balance with the amount absorbed by plants, forests, the oceans, and other "sinks." Since the start of the Industrial Revolution, CO_2 emissions have risen sharply, from 280 parts per million (ppm) in 1780 to more than 380 ppm in 2005.[11] About half of this excess CO_2 is absorbed by the Earth's sinks, but the rest accumulates in the atmosphere, amplifying the natural greenhouse effect through higher temperatures (National Academies 2008).

How do we know that Human Activities are Responsible for Climate Change?

There is mounting evidence from a variety of sources that confirms the link between human activities and climate change. The climate has exhibited considerable variations in the past, so it is conceivable that current trends are part of this natural cycle of variation. While acknowledging the many uncertainties, the scientific community has reached a near unanimous verdict that the GHGs generated by human activities are responsible for the current temperature increases.[12] This conclusion has been reached through numerous sources of scientific information. First, climate models show that observed temperature changes can be predicted only when human factors are included in the models (see Box 2.2). Second, the pattern of warming is consistent with the greenhouse effect, with greater temperature increases over land and in the Arctic than are occurring over the oceans. Finally, data from ice cores drilled from the Antarctic

Box 2.2 Role of Anthropogenic Greenhouse Gases in Global Warming

Human activities have changed the climate of the Earth. The figures below have been used by the Intergovernmental Panel on Climate Change (IPCC) to conclude that natural factors alone cannot explain the recent temperature changes. In the left panel below, the temperature projections are based on natural accumulations of GHGs and exclude the human-produced component of GHGs. There is a wide divergence between actual and projected temperature changes. The models suggest that when the anthropogenic component of GHGs is excluded, temperatures would be lower than they have been. The right panel includes projections with both natural and anthropogenic accumulations of GHGs included. The models track actual changes in temperature with remarkable accuracy.



Source: IPCC 2007a (reprinted with permission)

[11] Data on other GHGs in the 18th and 19th centuries are unavailable.

[12] This assertion is made by the IPCC 2007a with 90 percent confidence probability.

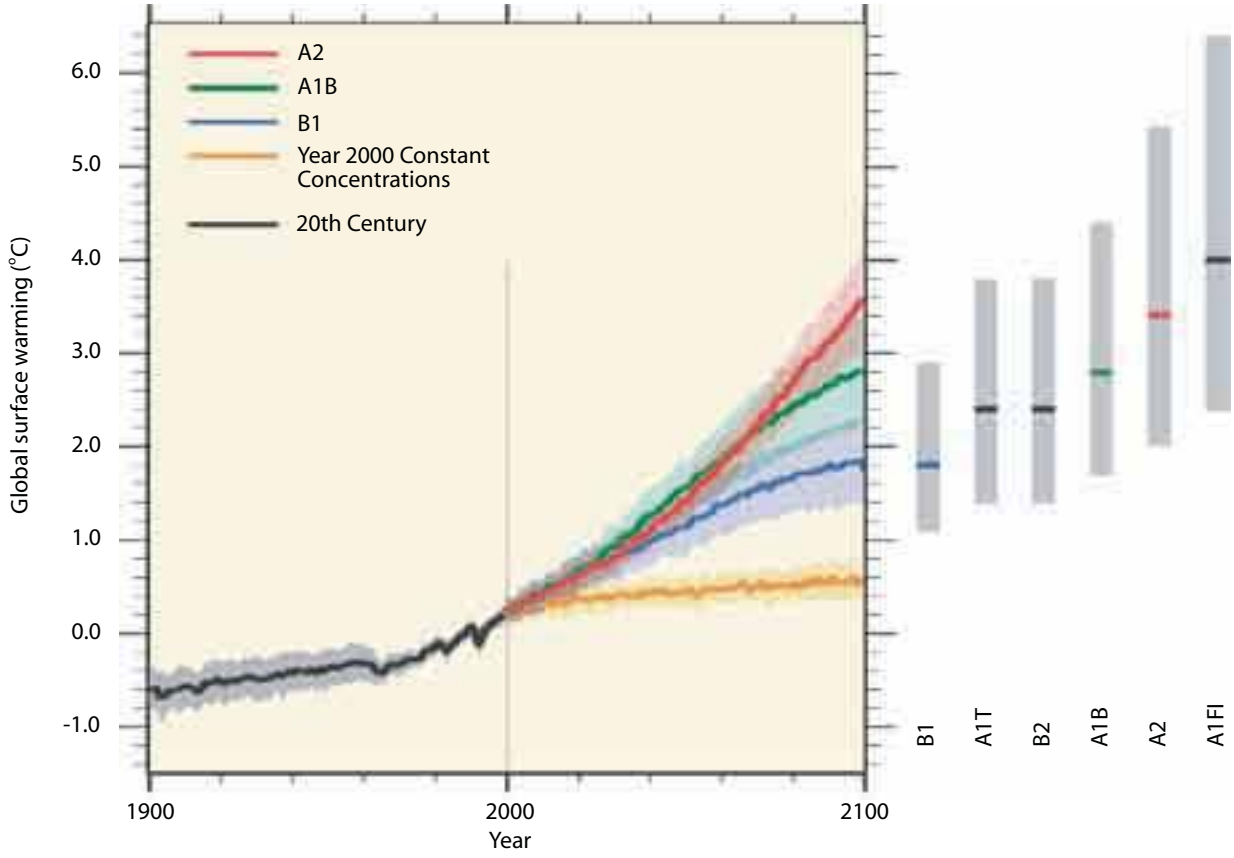
show that current CO_2 levels are higher than they have been in 440,000 years, and variations in CO_2 levels closely correlate with surface temperatures.

What might the Future Hold?

Projections of future climate change are much less certain. The extent of future climate change ultimately depends on global GHG emissions. These in turn depend on the scale and type of economic activities that will be undertaken over the next century. To compare possible outcomes the IPCC developed a variety of emission scenarios (Nakicenovic and Swart 2000) that span a range of plausible development pathways and possibilities. According to the IPCC *Fourth Assessment Report*, global GHG emissions will continue to grow in all plausible scenarios (IPCC 2007a). Figure 2.1 presents the various outcomes.

Three important messages emerge from these projections. First, despite the uncertainty in predicting future climate events, all the models suggest that there will be some degree of global warming. The projections cover a wide range of temperature increases—from a modest 0.6°C increase

Figure 2.1 Projected GHG Emissions and Global Surface Warming



Note: The graph 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 (reprinted with permission)

in the best-case scenario (with a low level of GHGs) to a potentially calamitous 6.4°C (with uncontrolled GHG emissions). Second, climate change is often viewed as a problem for the future, but some changes are projected to occur as early as 2020, regardless of potential mitigation actions (see the maps in Figure 2.2). Avoiding the negative impacts will require immediate adaptive responses to changing climate patterns. Third, higher concentrations of GHGs are associated with higher temperatures and increase the probability of harmful effects. In the worst-case scenarios emissions stabilize at about 650–750 ppm of equivalent carbon dioxide (CO_2e)[13] and carry a significant risk of temperatures rising by 5°C. The projected consequences would be highly undesirable, with parching droughts in parts of the subtropics, disappearance of the west Antarctic ice sheet, and some glacier melt in the high mountains of the world. A 5°C temperature rise also implies a higher probability that the "tipping point" would be crossed whereby changes become sudden, rather than gradual, with unpredictable shifts in climate patterns.

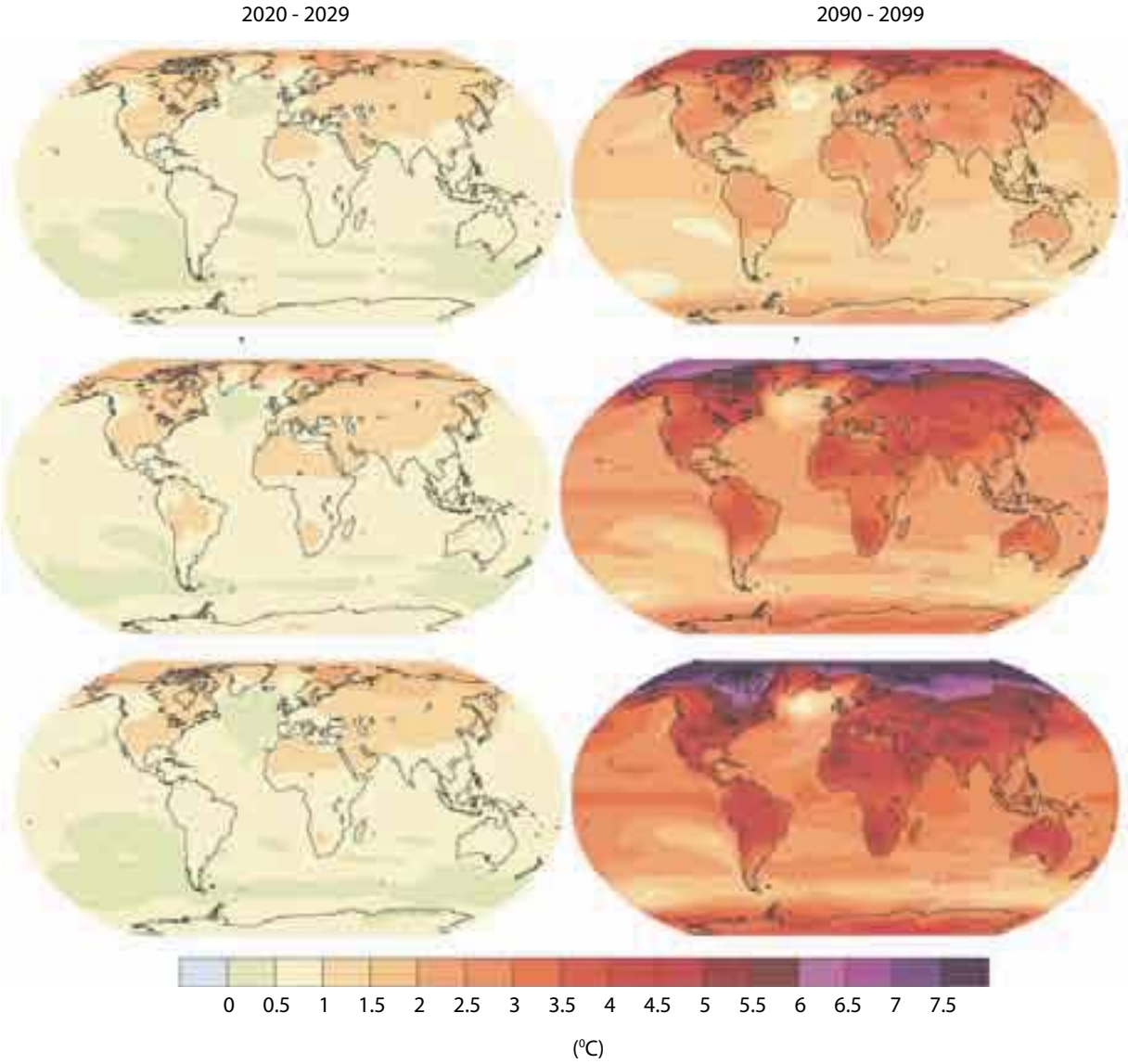
What are the Main Impacts of Climate Change?

There are many uncertainties in projecting the precise impacts of climate change on the economy. The response of physical systems to variations in climate is complex and often ambiguous. (See Box 2.3.) Even if these responses were known, the actual impacts would depend on how governments, organizations, and individuals react to climate risks. For instance, if there is early adaptation, some of the damage could be prevented. In other cases, losses

Michael Foley/World Bank

[13] See glossary for definition.

Figure 2.2 Projected Warming 2020–2099[14]



Note: The figures depict 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 (bottom row, most pessimistic), A1B (middle row, mid-range), and B1 (upper row, most optimistic). SRES scenarios averaged over decades 2020–2029 and 2090–2099.

Source: IPCC 2007b (reproduced/modified with permission)

may be unavoidable or even exacerbated by practices that increase exposure to climate risks (maladaptation). The likely impacts of climate change are projected to encompass all areas of development, but there are six that are of most concern. These are briefly addressed in the following paragraphs and covered in more detail in subsequent chapters in the South Asian context.

[14] IPCC scenario families contain individual scenarios with common themes. The six families of scenarios discussed in the IPCC's Third Assessment Report (TAR) and Fourth Assessment Report (AR4) are A1FI, A1B, A1T, A2, B1, and B2. A2 is characterized by high emissions, B1 is an optimistic outlook with much lower emissions, and A1B is an intermediate outcome.

Agriculture: Of all potential negative consequences of climate change, the damage to agriculture could be among the most direct and immediate. With their economies closely tied to the natural resource base and to climate-sensitive sectors such as agriculture, developing countries are expected to suffer significant losses from climate change. In some climate scenarios the colder temperate regions (of Northern Europe, Russia, and Canada) could reap short-term gains through higher agricultural yields because of rising temperatures. In contrast, in some developing countries temperatures are already approaching the limits of crop tolerance. Any further increase would lead to declines in productivity. Rain-fed agriculture and rangeland-based pastoral farming remain especially vulnerable to more variable climate patterns.

Water insecurity: Along with agriculture, the availability and distribution of freshwater remains a primary concern. The arid and semi-arid zones, often the poorest parts of the globe, are projected to face diminishing water supplies that could further jeopardize agriculture and livelihoods. Additionally, the retreat of some 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.

Natural disasters and extreme climate events: An overwhelming share of the world's natural disasters occur in developing countries, a problem made worse by the growth of poor communities along coastal areas. In the 1990s, climate-related disasters affected more than 2 billion people in developing nations, representing about 40 percent of the total population in the affected countries.[15] Although forecasts are uncertain, projections indicate that with warmer surface temperatures the seas will fuel more violent tropical storms, increasing the risks to coastal areas. There could be a higher incidence of other extreme events such as floods, droughts, and storms. Many countries are already extremely vulnerable to natural disasters. The challenge now is that the natural disasters are augmented by climate change.

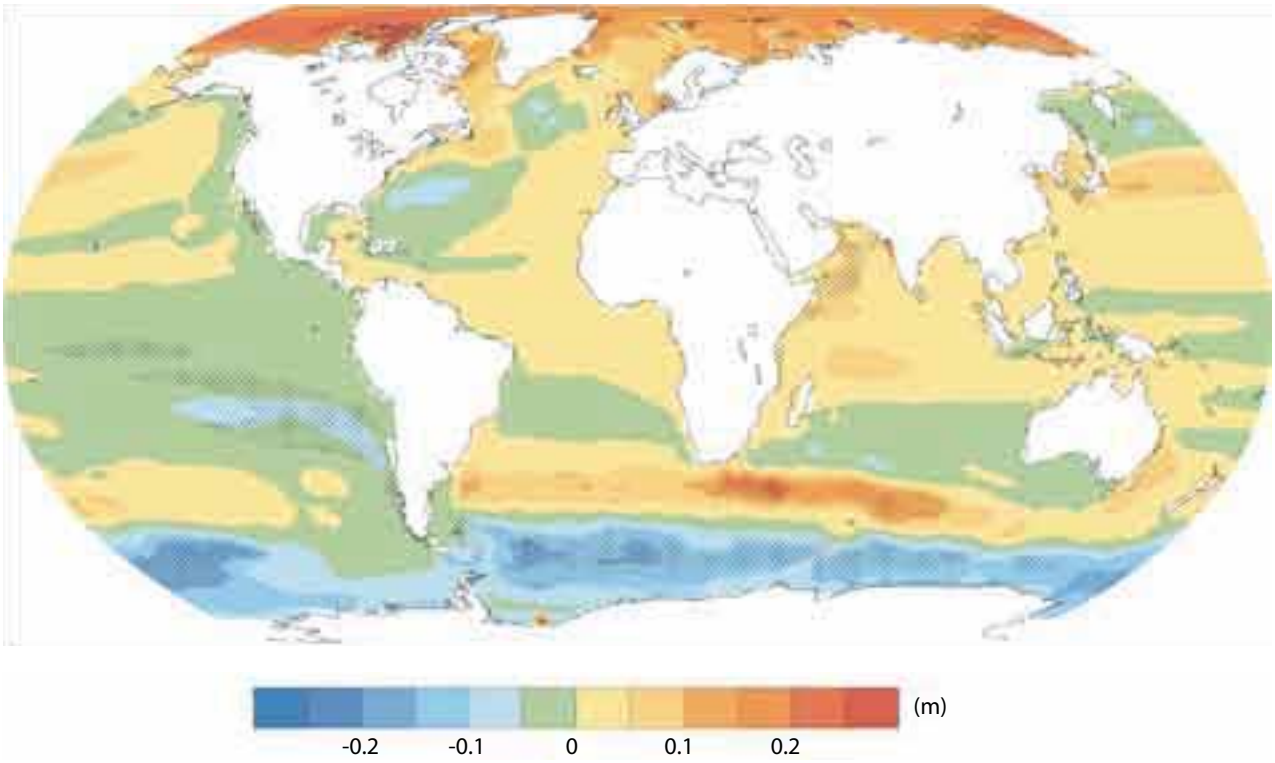
Sea-level rise: Sea-level rise threatens the existence of many small island nations and the development prospects of coastal economies (Figure 2.3). Estimated projections of sea-level rise by IPCC (2007c) for 2100 range from 9 to 88 centimeters, depending on the emissions trajectory. The threats are particularly severe for small island countries, which could be submerged in the worst-case scenarios.

Health: Climate change also brings new challenges for maintaining 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. Equally important in poor communities are the indirect effects caused by declining farm yields and food availability that could lead to malnutrition and a heightened susceptibility to other diseases.

Ecosystems and biodiversity: The links between biodiversity and climate change run both ways. Biodiversity is threatened by climate change, but proper management of biodiversity can reduce the impacts of climate change. Human pressures together with climate change are having a discernable impact on the productivity and resilience of ecosystems that are, in turn, critical for life-sustaining environmental services such as watershed protection, soil fertility, and carbon sequestration. The resilience of ecosystems can be enhanced and the risk of damage to ecosystems and humans can be reduced through appropriate adaptive strategies. Though information is sparse and knowledge is limited, research suggests that maintaining and expanding natural habitats remains among the most cost-effective strategies for building climate resilience.

[15] EM-DAT: The OFDA/CRED International Disaster Database, http://www.em-dat.net.

Figure 2.3 Sea-level Rise in 2080–2099 from 1980–1999 Levels



The figure depicts local sea level change (in meters) due to ocean density and circulation change relative to the global average during the 21st century, calculated as the difference between averages for 2080 to 2099 and 1980 to 1999. Positive values indicate local sea level change greater than global change. These results are from an ensemble (arithmetic) mean of more than 16 atmosphere-ocean general circulation models forced with the A1B scenario from the *Special Report on Emissions Scenarios* (SRES). 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 (reprinted with permission)

Confronting Climate Risks: The need for Adaptation

Substantial climate change is inevitable, so countries will need to adapt to those changes and reduce their exposure to climate risks. Climate change impacts the poor disproportionately because they depend heavily on climate-sensitive natural resources and subsist in an environment of scarcity where even small shocks can cause irreversible loss. Hence, climate change poses an additional risk to development and could potentially delay or reverse the attainment of many of the MDGs, including those on poverty eradication, child mortality, malaria and other vector-borne diseases, and environmental sustainability. Some of the resulting damages could be in the form of new challenges (e.g., sea-level rise) or severe shocks (e.g., extreme events) that countries are not equipped to handle. Others could emerge as existing threats (e.g., flooding or irregular rainfall) made increasingly severe by climate change.

Is Development the Remedy for Building Climate Resilience?

Development is necessary to build climate-resilient economies, but it may not suffice.

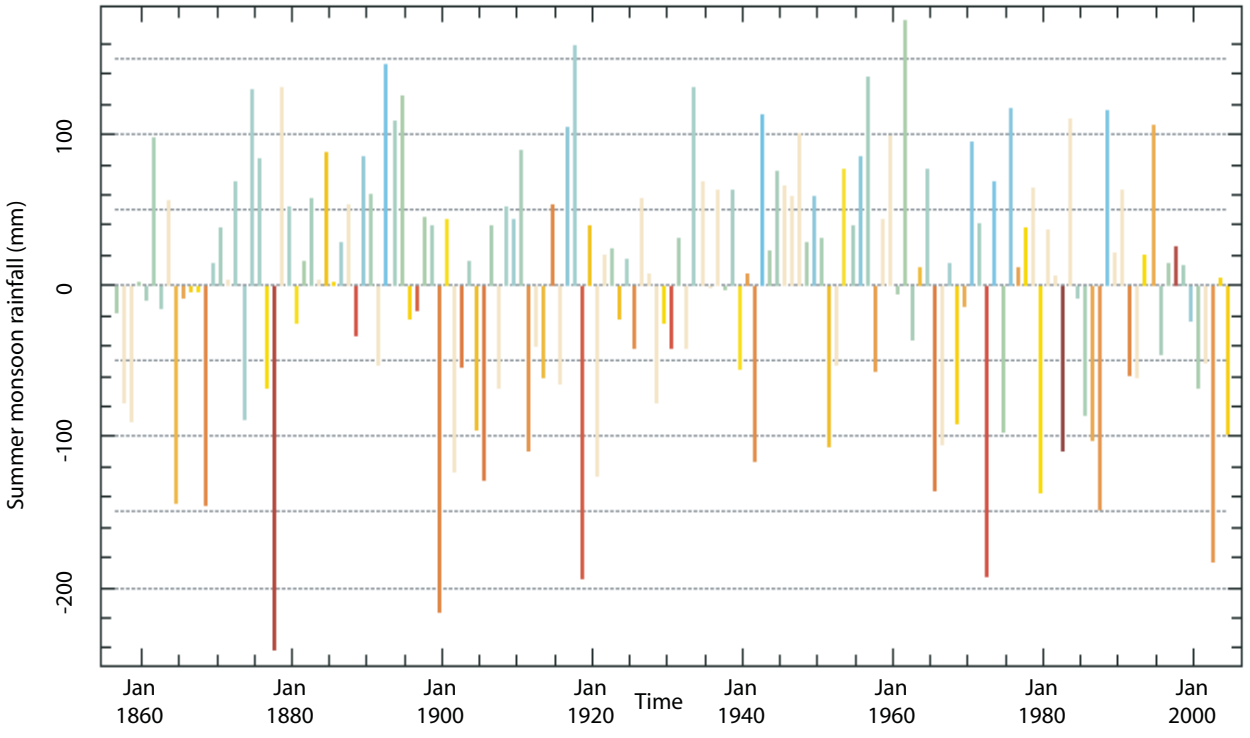
Box 2.3 A Word of Caution about Climate Models

Predicting the future is always a difficult endeavor. It is particularly challenging in the case of long-term climate change, which depends on a large number of parameters—temperature, precipitation, snow melt, and many others—with complex interactions. A number of increasingly sophisticated global climate models have been developed that can provide insight into possible future climate scenarios, particularly those arising from human development choices, offering the potential to further analyze the various environmental, social, and economic impacts of such choices and make appropriate decisions relating to climate-change adaptation.

Global climate models continue to evolve and improve, reflecting our growing understanding of complex biophysical and socioeconomic interactions and the use of more comprehensive databases, and their results have been interfaced with other models to downscale outputs to finer resolutions.

Despite these improvements in modeling techniques, the results can only be indicative of a very complex reality. Although many models agree on the broad climate-change implications at an aggregated spatial and temporal level, there is still significant divergence in results for specific locations or time periods in the future. The considerable uncertainty that remains in assessing the future trends of any one parameter (e.g., rainfall, temperature) is compounded when trying to predict how those parameters will interact with one another. For example, even if models show precipitation increases that may seem to be useful from, say, an agricultural viewpoint, the runoff or soil moisture may decrease due to increasing temperature and resulting evapotranspiration. Crop-water requirements and reservoir evaporation may increase, resulting in added demands and losses. This precipitation may also occur over shorter periods, thus increasing the threat of floods, droughts, and erosion.

Finally, complex climate interactions exist at a global scale. For example, rainfall in South Asia has been shown to be closely correlated with variations in the El Niño southern oscillation in the Pacific Basin. The figure below shows monsoonal rainfall variations against the norm over time. Variations in color shade reflect the intensity of hot El Niño events (red) and cold La Niña events (blue). The results indicate a close relationship between drought in South Asia and El Niño events in the Pacific. How climate change will affect the El Niño southern oscillation and its relationship with rainfall in South Asia is still unknown.



Sources: Rainfall data: Indian Institute of Tropical Meteorology (IITM). SST data: Kaplan NINO3 index from Optimal Smoother analysis of MOHSST5 monthly sea surface temperature anomalies

Economic well-being reduces vulnerability to climate risks. Developed countries are better equipped to deal with the impacts of climate change than developing countries. For instance, economic growth is typically accompanied by economic diversification, reducing the potential impact of climate change by spreading risk. Areas served by appropriate infrastructure will be more resilient to climate shocks. But the strategy of pursuing economic growth to combat the threat of climate change carries its own risks. First, climate variability itself may reduce growth capabilities. Second, climate change may outpace development, leaving the poor and vulnerable even more exposed to climate shocks. Third, vulnerability in the future depends not only on climate change but also on how development has been generated and sustained. A sustainable growth trajectory creates greater climate resilience by reducing the vulnerability of natural assets: for instance, healthy soils induce higher crop resistance to climate fluctuations. So the development paradigm of the past may not be enough, but development that integrates climate risks and sustainability would need to be part of the answer.

How should Developing Countries Adapt to the Risks of Climate Change?

The impact of climate change is diverse and the effects will vary across countries and sectors. Consequently, there can be no one-size-fits-all mindset when developing a climate risk-management approach. Any approach will have to be tailored to fit local risks and conditions. Appropriate policy will consist of a portfolio of options on risk management, at all levels of governance, and will include possible collaboration with private entities, local communities, and international agencies.

Climate change increases the costs of development. It alters the comparative advantage and productivity of many natural-resource-dependent economies. It calls for building climate-resilient infrastructure, which raises construction and maintenance costs. To counter the risks of natural disasters, greater investment is needed in preparing for disasters and building climate resilience. Estimates of the likely additional costs of adaptation vary widely, from a relatively modest US$4 billion a year to an exorbitant US$86 billion a year[16] Nevertheless, the provision of new and additional financial resources is essential to meet global development aspirations when faced with the burdens of climate change. Indeed, it was a commitment to such extra resources that provided the common ground to bind diverse parties to the Bali Action Plan in 2007.[17]

Are there limits to "Climate-Proofing?"

An effective response to climate change must combine adaptation to address the inevitable and mitigation to prevent the avoidable. Ultimately there are limits to the ability to adapt to fundamental and rapid climate change, and the economic costs would become prohibitive. It will not be possible to climate-proof countries or people against all possible climate outcomes, particularly if the changes become excessive. Adaptation to climate change therefore needs to be combined with mitigation. The two strategies are related and the cost of each will influence the global choice of policies for both. Hence there is a balance that needs to be struck.[18]

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[16] The lower bound is from the Bank's Clean Energy Investment Framework (CEIF) and the upper bound is reported in the United Nations Development Programme (UNDP) *Human Development Report 2007/2008* (Watkins 2007). It should be noted, however, that these figures are imprecise, make numerous assumptions, and use widely different approaches. Considerably greater research on both methodological and empirical issues is needed to provide more reliable figures.

[17] Bali Action Plan, http://unfccc.int/files/meetings/cop_13/application/pdf/cp_bali_action.pdf.

[18] To be precise, when interior solutions are available, the two policies (adaptation and mitigation) are strategic substitutes and thus a simultaneous decision on the optimal choices of each can achieve a given level of welfare at *lower cost* than sequential decisions in which one policy option is fixed first (for instance, adaptation) and the other (for instance, mitigation) determined in a subsequent stage.

The Global Emission Footprint

What are the Main Sources of GHGs?

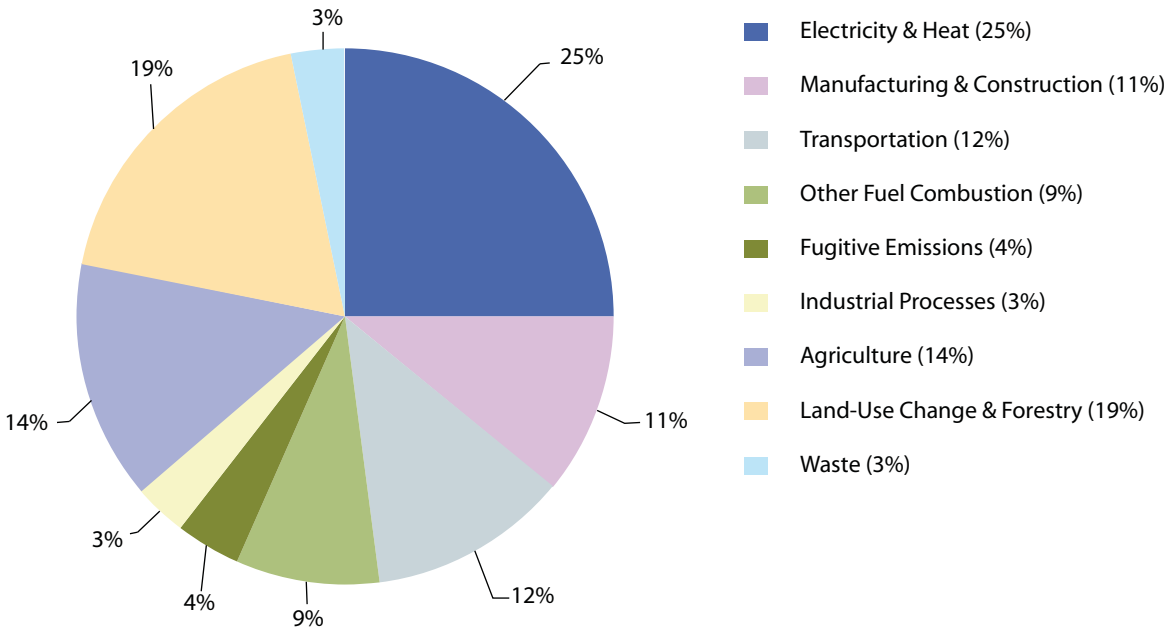
The emissions that drive climate change are ubiquitous and derive from almost every economic activity: transport, industry, energy use, agriculture, and deforestation. Energy-related emissions (from production, transformation, and consumption) account for more than 65 percent of GHGs, followed by deforestation, which contributes about 18 percent. The remainder comes from agriculture and wasteland use (Figure 2.4). Deforestation and fossil fuel consumption primarily produce CO_2, while agriculture and waste are the main sources of methane emissions. Methane is a highly potent GHG.

Which Countries are Responsible for Emitting GHGs?

Measuring a country's GHG emissions and consequent contribution to climate change is surprisingly complex and highly controversial. There are a variety of methods by which emissions can be measured, each producing different results and different country rankings. Historical emissions reflect a country's past responsibility for the current climate challenge. Current emissions reflect the ongoing additions to the stock of GHGs in the atmosphere. Other indicators, such as emissions per person or emissions per unit of production as measured, for example, by gross domestic product (GDP), offer more nuanced measures and acknowledge that countries differ in responsibility, circumstance and capacity to reduce GHGs.

Historical contribution of GHGs: Climate change is a consequence of the cumulative build-up of GHGs, dating back as far as the Industrial Revolution. It is therefore no surprise that developed countries are largely responsible for the build-up of GHGs 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

Figure 2.4 Sources of GHG Emissions



Total Emissions 40,809 Metric Tons (Mt) Co_2 in 2000

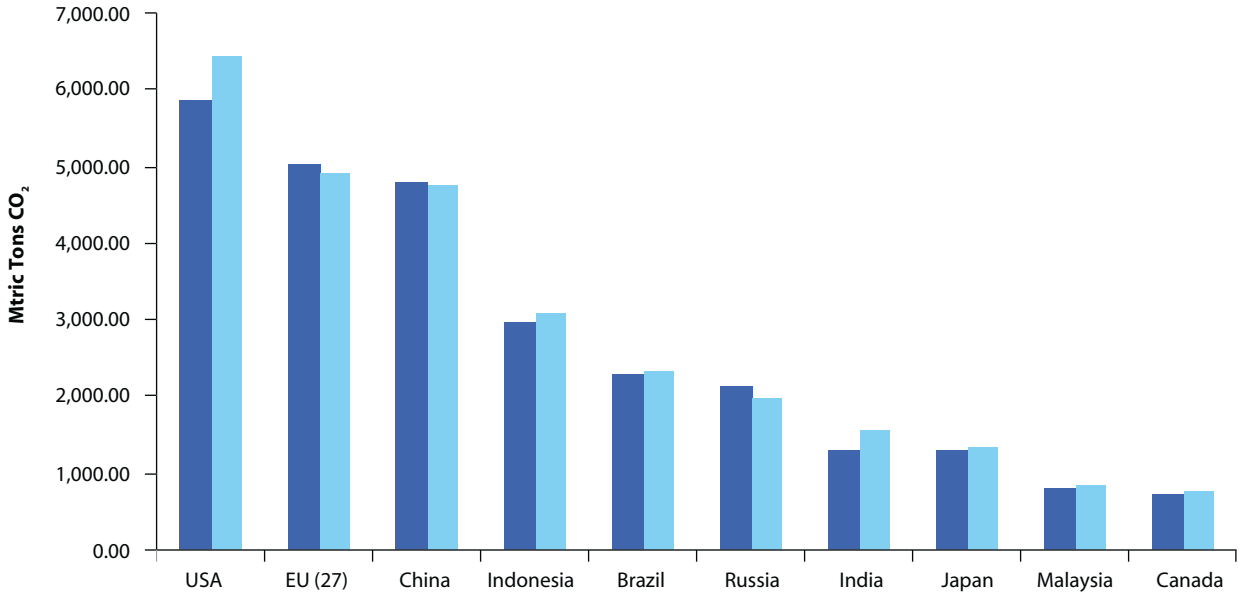
Source: WRI 2009

share of 29 percent), followed by the countries of the present European Union (26 percent) and Russia (8 percent).[19] Overall, developing countries have contributed only 24 percent to historical emissions, but their emissions are rising rapidly and at current trends would soon overtake the developed countries. Recognizing the importance of historical GHGs, there is a global statement that developed countries should take the lead in combating climate change.[20]

Current emissions: A relatively small number of countries, those developed and some developing, account for the bulk of current emissions. These countries are large emitters either by virtue of their burgeoning populations (such as China, Brazil, Mexico, and India) or their affluence (such as the United States and members of the European Union). In 2005 the largest emitters were the United States, the European Union, and China (Figure 2.5), which together accounted for about 40 percent of global emissions. More importantly, the 20 largest emitters are responsible for more than 80 percent of global emissions. The distribution of emissions is therefore highly skewed, but this also reflects the distribution of global GDP and population.

Emissions per person: The sheer size of population in some economies implies that to achieve any level of development they will need to consume considerably more resources (including GHG-emitting fossil fuel) and would therefore have larger total emissions. A ranking of countries based on per capita emissions standardizes for these differences.

Figure 2.5 GHG Emissions of 10 Highest Emitters, 1995 and 2000



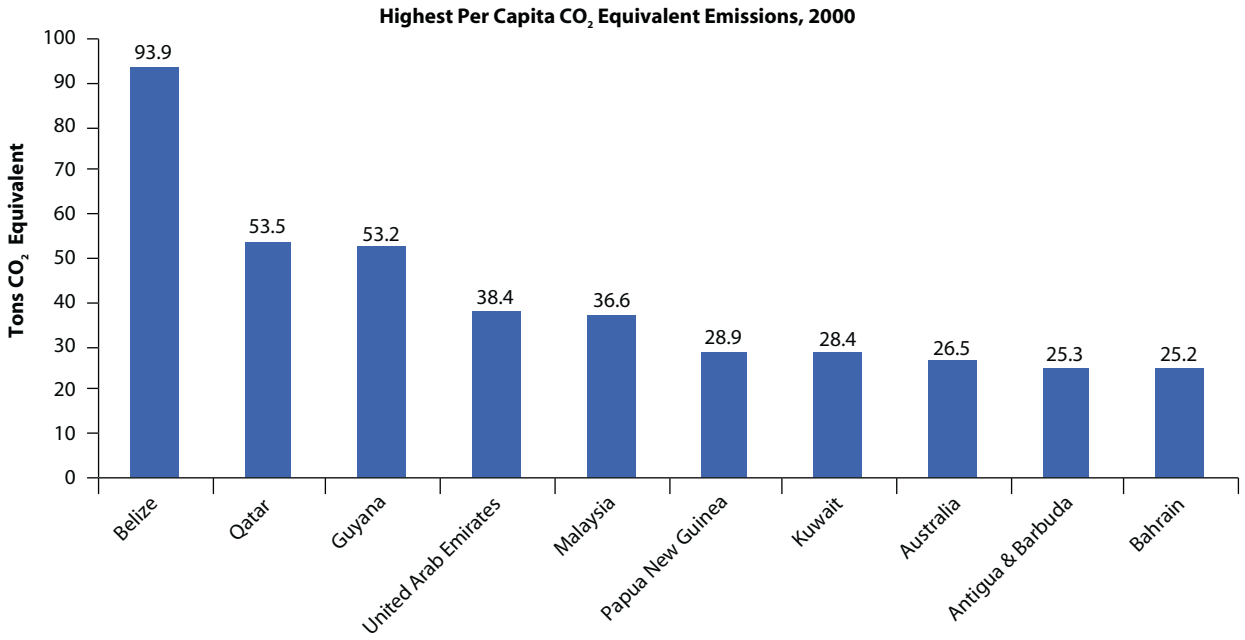
Source:. WRI 2009

In general, richer countries, with more affluent consumption patterns, tend to have higher emissions than poorer countries. However, generalization can be misleading as there are significant differences and variations within any cluster of countries ranked by development levels. Figure 2.6 shows countries

[19] These figures are based on emissions from 1850 to 2002. The European Union is treated as a single party reflecting its status in UNFCCC.

[20] Article 3.1 of the United Nations Framework Convention on Climate Change (UNFCCC), http://unfccc.int/essential_background/convention/background/items/1355.php) and paragraph 1(b)(i) of the Bali Action Plan (http://unfccc.int/files/meetings/cop_13/application/pdf/cp_bali_action.pdf.

Figure 2.6 Countries with the Highest Per Capita CO_2eq Emissions,[21] 2000



Source: WRI 2009

with the largest per capita emissions; the list includes both developed and developing countries.

What Determines Per Capita Emission Levels?

Per capita emission levels are influenced by resource endowments and geography. In some countries an abundance of fossil fuels has created a comparative advantage in pollution-intensive activities (e.g., coal in Australia and oil in United Arab Emirates). In other cases, deforestation has contributed to high levels of per capita emissions. Colder countries, though often wealthier, have greater heating needs and as a result are predisposed to higher per capita emissions. This variability in per capita emissions has troubling implications for global agreements to reduce emissions. An international agreement predicated on per capita entitlements would likely face difficulties in garnering support, for example, from the low-income countries with higher per capita emissions than many developed countries.

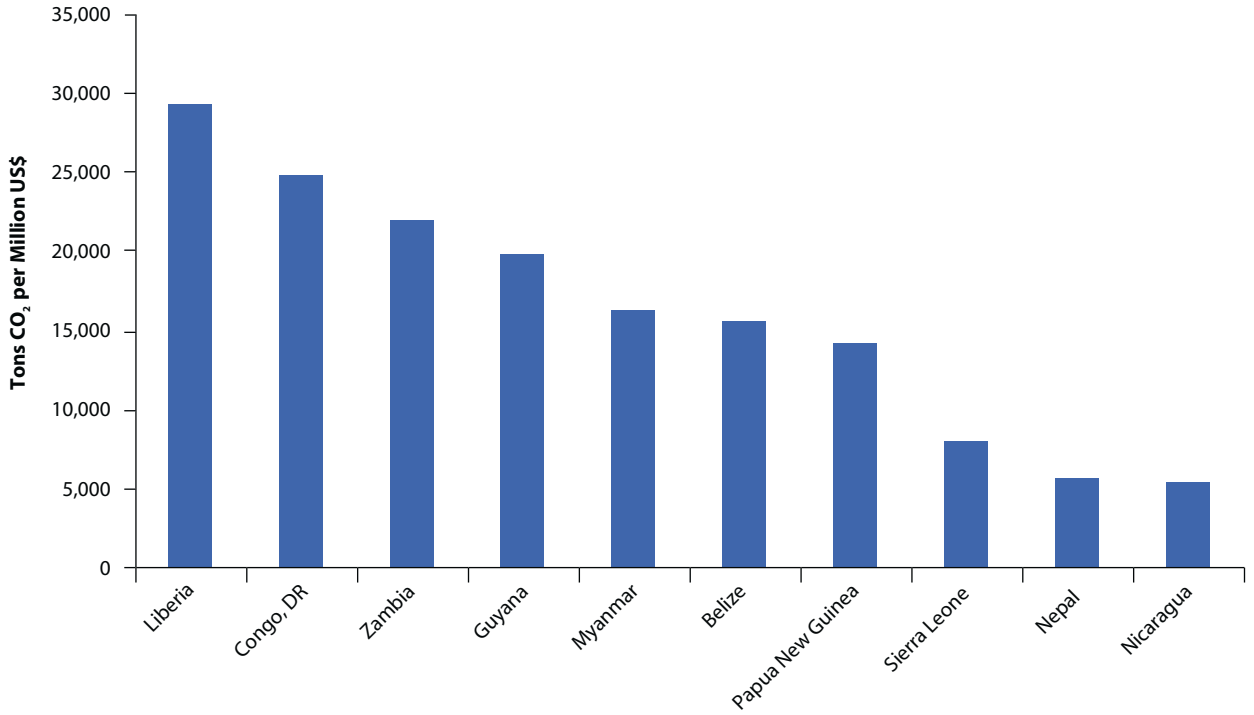
Emission intensity: Emission intensity measures the amount of GHG emitted per unit of GDP output. It varies widely across countries at all levels of development and income (Figure 2.7). There are three key factors that determine a country's emission intensity. First, in economies with rapid growth, emission intensity declines over time as GDP typically increases faster than emissions.[22] Second, the emission intensity in a country reflects its economic structure and the mix of agriculture, manufacturing, and services. Clearly, in some sectors (such as cement production) more pollution is generated in producing a unit of value than in other sectors (such as banking and insurance). Finally, emission intensity also depends on the mix of fuels used to generate electricity, and the efficiency of energy use.[23]

[21] See glossary for definition.

[22] This is an obvious arithmetic necessity because the emission elasticity of GDP must be less than unity in any economy with a diversified economic structure comprising sectors that encompass low and high pollution-intensive industries.

[23] As with all other measures, rankings based on emission intensities remain controversial. In an increasingly globalized world products are exported across national boundaries. Emission intensities attribute pollution to the source of production and not its destination of consumption.

Figure 2.7 CO_2 Intensity: Main Emitters, 2000



Source: WRI 2009

At What Level should the World Stabilize GHG Emissions?

Determining the appropriate stabilization level and path remains the most controversial and divisive issue in global climate negotiations. The current level of GHG concentrations is approximately 430 ppm CO_2e and is rising at about 2 ppm each year.[24] Some favor rigorous and immediate stabilization of emissions; others propose a more cautious approach and emphasize the need for addressing priorities such as poverty and the MDGs. There are two broad analytical approaches that guide judgments on the appropriate stabilization path: the precautionary approach (following the precautionary principle) and the economic approach.

The precautionary approach: The precautionary principle places a high priority on avoiding calamitous and irreversible outcomes, even if these are highly uncertain. This is the view advocated by the United Nations Development Programme's *Human Development Report* (UNDP 2007), which calls for stabilization at 450 ppm CO_2e, an emission level that will likely produce a 2°C to 3°C increase in temperatures. The approach aims to avoid concentrations that would risk reaching tipping points: levels at which feedbacks would cause GHG concentrations to rise further through, for example, the release of methane from permafrost (mostly in the Arctic regions), release of carbon dioxide from oceans, and increased solar radiation from polar icecap melts, resulting in a rapid rise in temperatures with largely unknown consequences. Critics of this approach contend that with the many uncertainties and the large unknowns the risks of wasteful expenditure on mitigation could outweigh the potential costs of climate change. The suggested approach involves a wait-and-see

[24] The implication is that the Earth is likely committed to a 2°C warming.

stance, with an early emphasis on adaptation followed by mitigation if this becomes necessary (Lomborg 2007).[25]

The economic approach: Economics have searched for strategies that balance the costs of intervention with the perils of inaction. Assessments compare the expected costs of reducing or stabilizing GHGs (mitigation) with the expected benefits of emission reductions (in terms of avoided climate damages). There is broad agreement on the likely costs of stabilizing emissions. These are typically estimated in the range of 3–5 percent of GDP (IPCC 2007a; Heal 2008).

However, there is little consensus on the benefits of mitigation, defined as the avoided costs and damages from climate change. Estimates of the avoided damage from climate change vary from a low figure of 1 percent of GDP (Nordhaus 2006) per annum to a dramatic 5–20 percent (Stern 2006; Sterner and Persson 2007). A damage estimate of 1 percent of GDP is within the margin of GDP accounting error, and suggests the need for a highly circumspect approach to mitigation. Conversely, high damages of 5–20 percent would justify early mitigation measures to avoid the high costs and possibly catastrophic outcomes. The large differences reflect the weight given to future impacts and the factors included in the calculation of climate damages. Low estimates are obtained when the damage assessments leave out nonpecuniary losses—in particular the loss of vital environmental services[26]—or place a low weight on damages in the distant future (termed the discount rate).

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Who is Right, the Climate Optimists or the Climate Pessimists?

The solution to the climate challenge lies not in impeding development and growth, but in finding strategies that weaken the link between economic activity and GHG emissions. Since growth spurs emissions in very rough proportion to the income it generates, there are legitimate concerns that mitigation would jeopardize other urgent development priorities, such as energy access, education, health, and nutrition. The ultimate solution to the climate challenge therefore lies in finding strategies that decouple economic activity and GHG emissions. New technology would need to play a pivotal role in finding longer term solutions to this far reaching problem.

An overarching challenge in addressing climate-related problems is the asymmetry in the cause of the problem and impacts across countries. The developed countries have contributed most to existing stocks of GHGs, but it is the developing countries, with their dependence on climate-sensitive sectors, who will be disproportionately affected. To address this problem will call for an unprecedented level of global cooperation and a substantial transfer of resources both to address

[25] The counter to this is that it would be too late to arrest the damage because of the long lags in climate systems. CO_2 endures in the atmosphere for about a century. Consequently, current climate impacts are a consequence of the atmospheric build-up of previous generations.

[26] Sterner and Perrson (2007) demonstrate this outcome in the Nordhaus model, which has typically produced low-end estimates.

the development challenges imposed by climate change and to slow the process of climate change. There is a governance challenge at the global level that requires collective action among nations and among groups within societies to ensure fair and equitable access to the global atmospheric commons. Global and regional cooperation will be crucial, given the potential damage that free riding can inflict by undermining mitigation by others. In the short term, this will mean making substantial resources available to ensure that developing countries do not have to suffer the costs of any chosen emission stabilization path. In the longer term, technology may provide the answers needed to sustain growth in a carbon-constrained world.

Chapter 3 identifies the broad impacts of climate change in South Asia and the region's contribution to the problem. It outlines the reasons why the region is highly vulnerable to the impacts of climate change, with a particular focus on the likely high impact sectors.

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CHAPTER 3

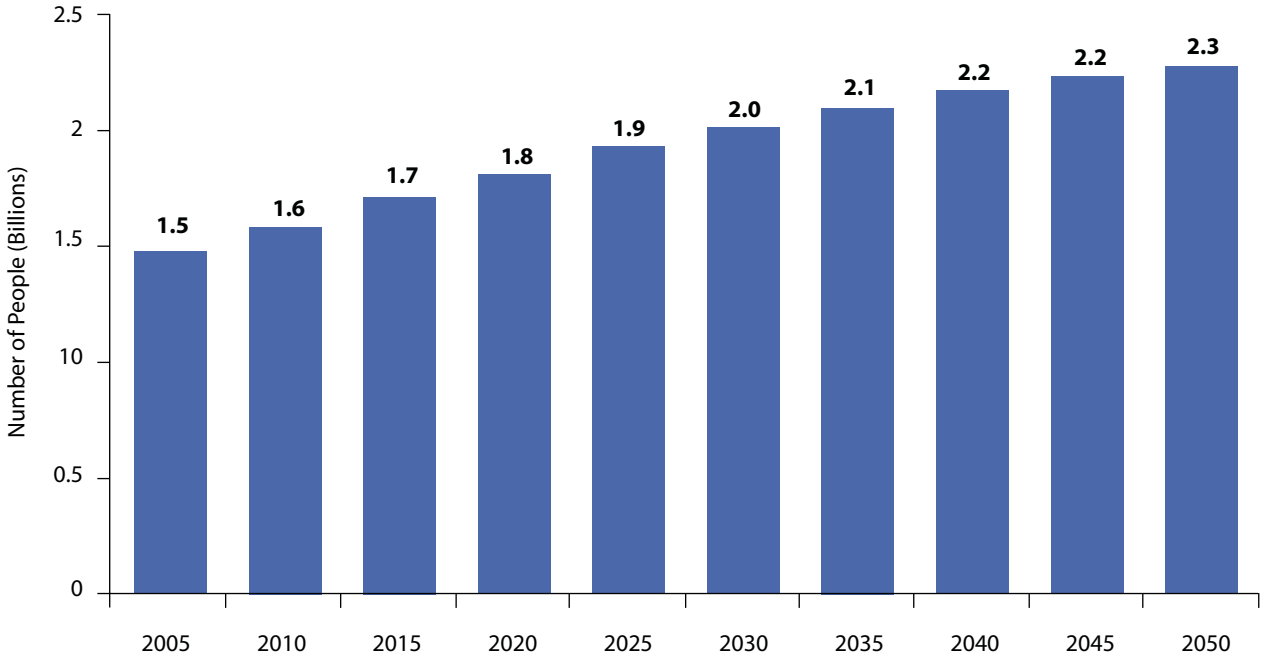
The Regional Scene: South Asia's Climate Vulnerability and Contribution to Greenhouse Gas Emissions

CHAPTER 3
The Regional Scene: South Asia's Climate Vulnerability and Contribution to Greenhouse Gas Emissions

Why is South Asia Vulnerable to Climate Change?

Geography coupled with high levels of poverty and population density has rendered South Asia especially vulnerable to the impacts of climate change. The region faces daunting climate-related development challenges. The likely impacts of climate change in the form of higher temperatures, more variable precipitation, and more extreme weather events are already felt in South Asia. It has been projected that these will intensify. High population levels translate into increased resource demands on an already stressed natural resource base. By 2050, South Asia's population is likely to exceed 2.2 billion from the current level of 1.5 billion (Figure 3.1). With an estimated 600 million South Asians subsisting on less than US$1.25 a day, even

Figure 3.1 South Asia Population Projections



Source: World Bank 2009

small climate shocks can cause irreversible losses and tip a large number of people into destitution.

Through much of South Asia, poverty is still largely in the rural areas and closely intertwined with natural resource degradation. About 70 percent of South Asians live in rural areas and account for about 75 percent of the poor. Most of the rural poor depend on agriculture for their livelihoods. Agriculture employs about 60 percent of the labor force but contributes only 22 percent of regional GDP. With their rural economies closely tied to the natural resource base and climate-sensitive sectors such as agriculture, the poor in South Asian countries are likely to be disproportionately affected by climate change.

The region is already marked by climate variability and a high incidence of natural disasters. South Asia's climate is as diverse as its landscapes. The region's geographic expanse covers a variety of climate zones and ecosystems ranging from lush tropical forests to arid deserts and high-altitude forests and lakes. Climate risks in the region reflect these varying conditions with regular droughts, floods, wind storms, and tropical cyclones. The region is highly susceptible to natural disasters. More than 750 million people, about half of the region's population, have been affected by at least one natural disaster in the past two decades. The region shares common geological formations and river basins, and natural hazards frequently transcend national boundaries. With climate change the frequency and incidence of such natural disasters is projected to increase.

Compounding these risks is the region's heavy reliance on the monsoons. The monsoon is the most significant climate event in the region's economic calendar. It carries more than 70 percent of South Asia's annual precipitation in a brief four-month period. The monsoons also exhibit substantial annual variations. A buoyant and timely monsoon heralds bountiful harvests and financial security. However, when the monsoons fail or are excessive, suffering and economic loss are widespread. About 60 percent of the cultivated area is rain-fed, and hence the rural economy of South Asia critically depends on the timely arrival of the monsoons. The worst affected are the landless and the poor, whose primary source of income is agriculture. If climate projections are indicative of future trends, the risks associated with water-related climate variability are likely to worsen.

The Himalayas have a significant influence on the climate and economy of the region. The Himalayan system shapes the critical and often unpredictable monsoon dynamics. It acts as a natural reservoir for sustaining crops and providing groundwater recharge. In fact, it is home to a unique ecosystem. The Himalayan ecosystem sustains some 1.5 billion people who live directly in the floodplains of its many rivers (e.g., the Brahmaputra, Ganges, Indus, and Meghna). The Ganges River Basin alone is home to about 600 million people (see Figure 3.2). The retreating of some glaciers in the Himalayas could present the most far-reaching challenge to the region. The Himalayas are home to the region's glaciers, which are sensitive to increases in temperature. Some glaciers are receding more rapidly than the global average, leading to increased

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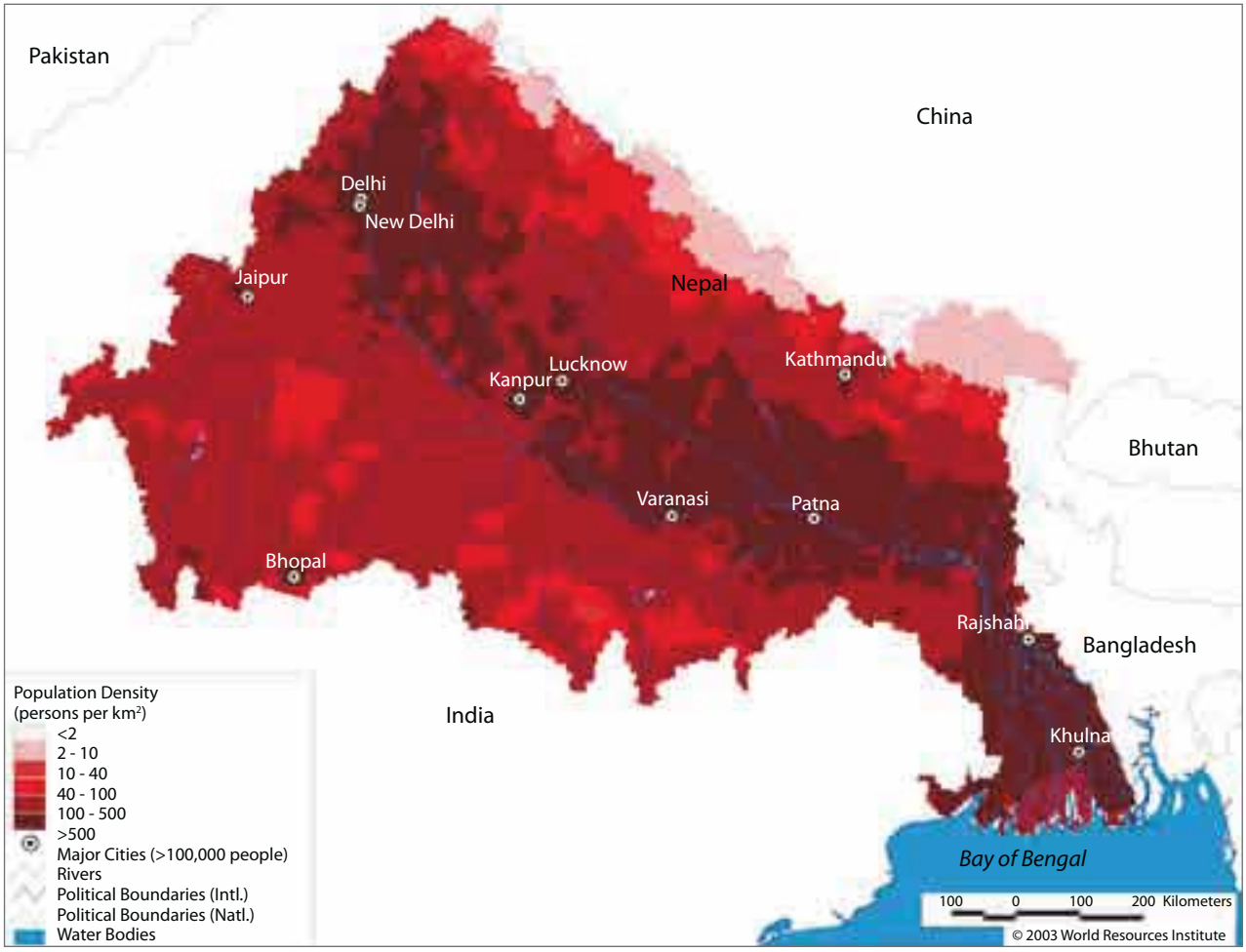
Figure 3.2 Ganges River Basin



Source: WRI, 2003

threats of glacial lake outburst floods in Bhutan and Nepal (see Figure 3.3). This poses an unprecedented threat to water supplies, lives, and the economy of the region. With melting of some glaciers, flood risks would increase in the near future. In the long term, there can be no replacement for the water provided by glaciers, and this could result in water shortages at an unparalleled scale. Such an occurrence could necessitate a shift in the economic activities away from water-intensive activities. A very important point to be noted is that the risks cut across borders and are regional. Possible glacier retreat in Nepal, for instance, can flood farms in distant Bangladesh, and climatic variations in, for example, China may impact some glacier retreat in South Asia. Addressing these problems calls for considerable regional cooperation.

The region has a long and densely populated coastline with low-lying islands that are vulnerable to sea-level rise. Sea-level rise is a major source of concern not only for coastal urban areas (e.g., Chennai, Cochin, Karachi, Kolkata, and Mumbai) but also for the fertile delta systems, which are threatened by both inundation and salinity intrusion (e.g., in Bangladesh and the river deltas of the Cauvery, Indus, Krishna, and Narmada). Saltwater intrusion in low-lying agricultural plains and water resources could lead to localized food insecurity, the spread of water-related diseases,

Figure 3.3 Glacial Lakes from Retreating Glaciers

This image from the ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) instrument aboard NASA's Terra Satellite shows the termini (the ends) of the glaciers in the Bhutan-Himalaya. Glacial lakes have been rapidly forming on the surfaces of debris-covered glaciers worldwide during the last few decades.

Source: NASA, 2002

and the contamination of freshwater reserves. Parts of the east coast (Bangladesh and the Indian state of Orissa) are particularly vulnerable to cyclones and storm surges, and some projections suggest that these could become more devastating in the future. Low-lying islands (the Maldives, coastal areas of Sri Lanka, and the chars and islands of Bangladesh) stand most to lose from sea-level rise and the threat of coastal storms. The natural mangroves (Sundarbans) and coral reefs that have helped buffer some of these impacts would vanish if there is a significant climate change.

Urbanization poses an additional challenge in the region. South Asia is home to some of the fastest growing cities in the world. South Asia's burgeoning cities are seen as its icons of development, having fueled much of the investment and economic diversification that has underpinned rapid growth. The cities account for more than 25 percent of regional GDP, and their ability to attract and retain investment has a direct impact on overall economic performance. On the other hand, rapid urbanization has been accompanied by increased climate-related vulnerabilities and a steady deterioration in the quality of the urban environment. Projections indicate that in three decades about half the region's population will dwell in the cities. (See Figure 3.4.) By 2020, Mumbai will be the second largest city in the world, closely followed by Delhi and Dhaka. Together with Karachi and Kolkata, five of the world's 11 megacities will then be in South Asia. Dhaka is already the fastest growing megacity in the world, drawing an estimated 300,000 to 400,000 mostly poor migrants each year. In Mumbai, more than half the population is crowded into about 2,000 densely populated

slums that are at risk from flooding and where settlements lack basic protective infrastructure. There are particular challenges in making cities climate resilient. Building urban resilience requires improving infrastructure, governance, and finance. Without a substantial investment in basic amenities and infrastructure in these large cities, climate change will exacerbate existing vulnerabilities.

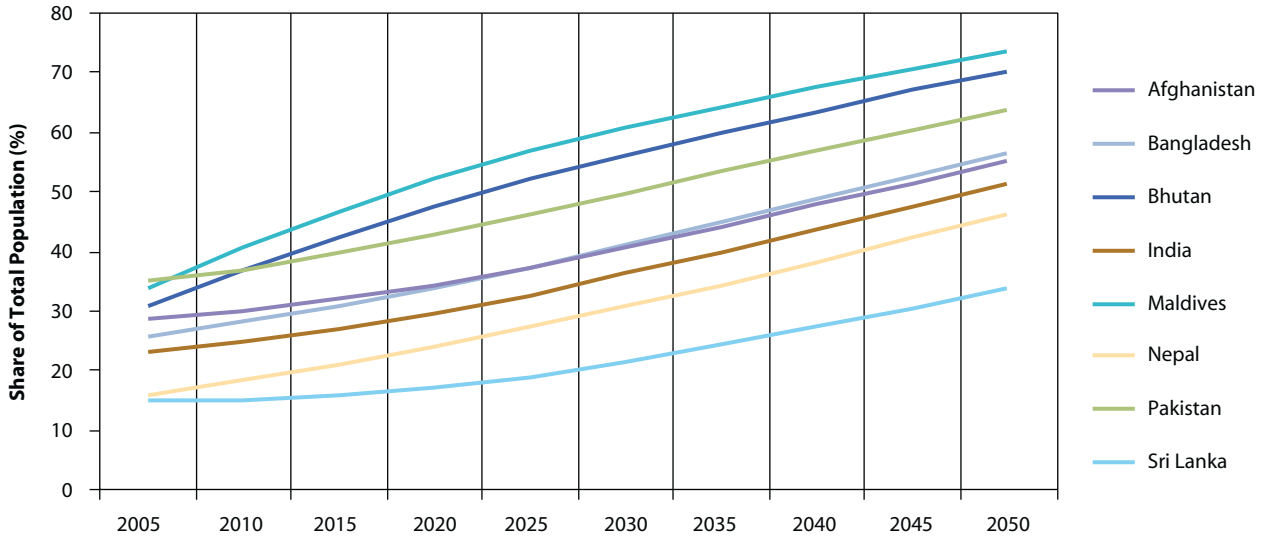
In sum, high population densities, a large concentration of poverty, and climate variability have all combined to make South Asia highly sensitive to the likely consequences of climate change. Climate change will likely compound the pressures on key resources associated with growth, urbanization, and industrialization. The appendix provides a snapshot of risks and climate profiles for each country in South Asia.

Rapid economic growth has been instrumental in reducing poverty in South Asia. During the 1990s, South Asia's economies grew rapidly at an average of 6 percent annually. Growth further accelerated to 6.5 percent during 2000–2007 and has lifted millions out of poverty. South Asia, however, is the least integrated region in the world and would grow further if its markets were more integrated. Regional cooperation can be a powerful tool for increasing growth, reducing inequality, increasing energy trade, and reducing vulnerabilities for the poor. Climate change will reinforce the need for greater levels of economic integration. For instance flood risks, population displacement, and the spread of climate-sensitive diseases are likely to transcend national boundaries. Regional cooperation can be helpful in addressing climate risks and lowering income inequality. Likewise, regional energy trade can contribute to the goal of low-carbon development. The challenge for South Asia is to maintain high growth rates while being climate resilient, environmentally sustainable, and inclusive.

What might the Future Hold for South Asia?

Projecting climate futures is a daunting task. Changes will depend on the unknown future path of GHG emissions, the response of physical systems to emission levels and, nonlinear feedback processes. While acknowledging the many uncertainties a broad consensus has emerged

Figure 3.4 South Asia Urban Population Projections



Source: UN 2007

about the likely risks and patterns of climate change under various scenarios developed by the IPCC. This section focuses on the primary climate variables: temperature; precipitation; runoff and the major consequences. The Appendix contains more scientific details.

Temperature

There is broad consensus 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 is projected to 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 experiencing a rise of 1.5°C to 2.5°C in the moderate scenario put forward by the IPCC.[27]

Precipitation

The projections suggest that the wet regions will get 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. IPCC projections indicate that the number of days for which extreme events last (especially floods and droughts) would increase in duration and severity. This effect will be especially pronounced in South Asia with its reliance on the monsoons.[28]

Michael Foley/World Bank

Runoff

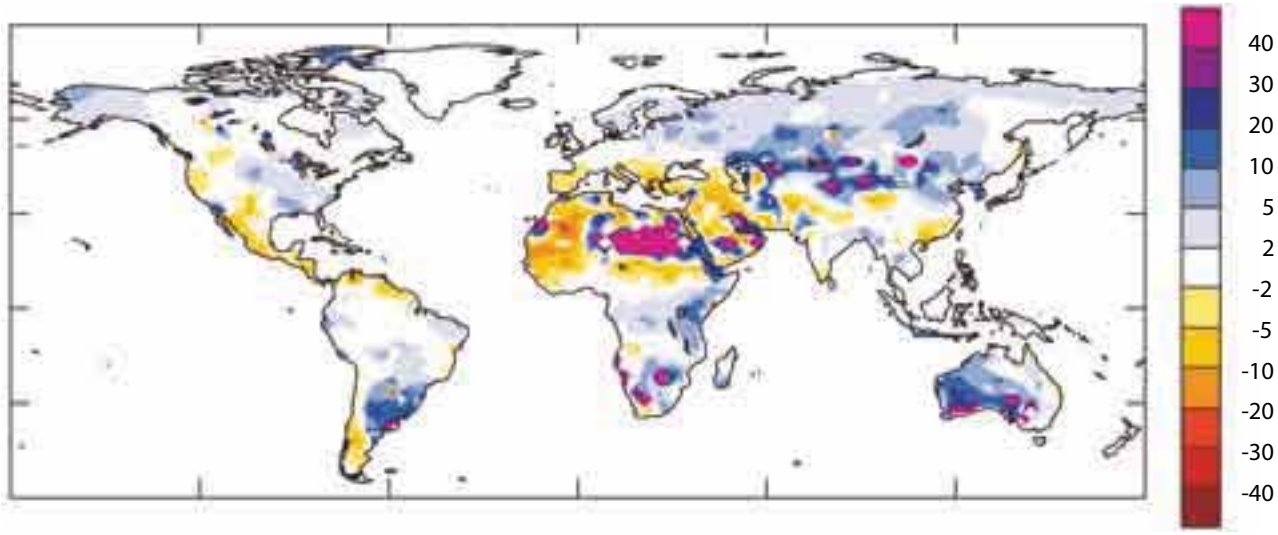
Changes in precipitation and temperature are expected to interact in complex ways to change the balance between "green" water and "blue" water. "Green" water is the water that is used or lost in catchments before it reaches the rivers, while "blue" water is the runoff that reaches the rivers. The runoff is expected to change significantly in the subcontinent (Figure 3.5), with implications for agriculture. The Indus and Ganges/Brahmaputra Basins are expected to experience increased runoff driven by precipitation changes and glacial melt. After the glacial melt, however, there could 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 implications for storage, irrigation, and the development and reliability of hydropower systems. Such outcomes will be further complicated by changes in water use in the basins including diversions, groundwater-surface water interactions, and increased demands for irrigation, hydropower, industrial, and municipal water supplies by the increasing population.

[27] This is one of the scenarios used by the IPCC in its climate projections. It is moderate in its assumptions about the world and the pace at which it will change. For instance, it assumes low rates of population growth and land-use changes; medium availability of resources such as oil and gas; very high GDP and energy-use growth; and rapid technological change, among other things (Nakicenovic and Swart 2000).

[28] However, evidence presented in the India National Communications finds that there is no statistically discernible trend in the monsoons. This is because the monsoons have always exhibited high stochastic variation and a stable core remains. (Source: Government of India, Ministry of Environment and Forests 2004).

Figure 3.5 Relative Change in Runoff in the Twenty-first 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.

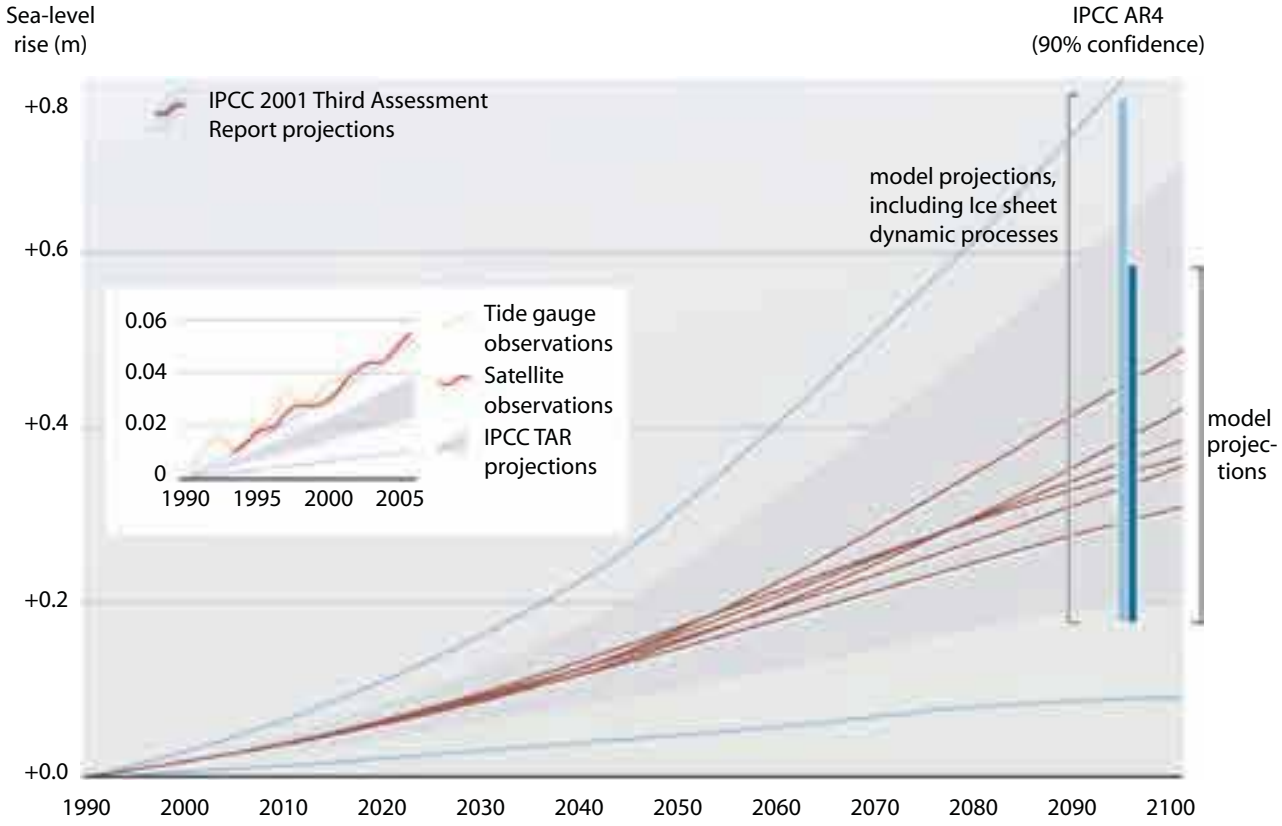
Source: Milly, Dunne, and Vecchia 2005 (reprinted by permission from Macmillan Publishers Ltd)

Sea-level Rise

Sea-level rise could have a significant impact on the low-lying coastal systems and islands. While there are uncertainties on the extent of change, the IPCC Fourth Assessment (Figure 3.6) projects a mean of about a 0.4 meter rise by the end of the century, excluding future changes in possible glacier melt.[29] In India and Pakistan the current rise in sea level is reported to be about 1.0 millimeter per year. Bangladesh is particularly vulnerable, with estimates of sea-level rise varying from 0.30 to 1.5 meters by 2050 under alternative scenarios (Broadus 1993). Whatever the magnitude, the rate of increase of sea-level rise is not a linear function of time. Sea-level changes have direct inundation impacts and indirect effects such as changes in salinity levels, enhanced storm surge effects, changing sedimentation patterns, and changes in ocean currents. The most vulnerable country in South Asia is the Maldives, which consists of low-lying islands scattered in the Indian Ocean. Most islands (96 percent) occupy less than 1 km^2 of land and 80 percent of the country lies below one meter sea level. Sea-level rise could pose an existential threat and is projected to submerge much of the country in the worst-case scenarios.

[29] There are numerous other projections of more severe sea-level rise that allow for greater melting of polar ice mass.

Figure 3.6 Projected Global Average Sea-level Rise at the end of the Twenty-first Century



Source: Ahlenius 2007 (reprinted with permission)

Climate-related Disasters

Climate change is likely to increase the intensity and incidence of many climate-related natural disasters. South Asia is subject to a range of climate-related disasters, including tropical cyclones, sand storms, floods, and droughts. Although it is difficult to predict the relationship between storms and climate change, it is expected that, around the world, there will be more storms, at higher intensity. Projections for cyclone intensity in the Bay of Bengal are mixed, with some studies suggesting higher intensities with lower frequency (Government of Bangladesh 2002, 2005). Floods and droughts are also expected to increase, given predictions of higher precipitation in fewer days. Floods are likely to continue being a major problem in Bangladesh, Bihar, and Uttar Pradesh in India and a significant problem in many other places vulnerable to flash floods. Vulnerability to natural disasters is of particular concern because of the region's high population density and poverty.

Coordination between the disaster-risk management and the climate-change agendas will become essential. Many of the impacts associated with climate change alter the risk profile of existing hazards, such as floods, droughts, cyclones, and other extreme weather-related events. Adaptation measures can benefit from the practical experience in disaster management. Enhancing the ability of local communities to manage current natural hazard risks will improve capacity to prepare for and respond to future climatic changes. In this context, the disaster-risk mitigation and climate adaptation agendas require an integrated approach.

Glacier Retreat

There is general agreement that widespread retreat of the global ice cover has been occurring since at least the early 1800s. With rising temperatures, the ice mass of the Himalayan-Hindu Kush is retreating more rapidly than the global average in some locations. The Gangotri glacier (see Figure 3.7) is the source of the Ganges and is one of the largest in the Himalayas. The Gangotri has been receding since 1780 and in recent years the pace of retreat has accelerated.[30] The receding trends of glacier masses threaten water supplies, livelihoods, and the economy of the region. Agriculture and the region's economic structure will need to undergo significant adjustment to cope with these changes.

Who will be most Affected by Climate Change?

The poor and marginalized are likely the most vulnerable to climate risks. Climate change

Figure 3.7 The Gangotri Glacier, India: Past 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: NASA 2001 (reprinted with permission)

[30] During the period 1975 to 1999, the glacier has retreated more than 850 meters, with a 7-meters loss from 1996 to 1999 alone. However, many scientists believe that it is premature to make a statement that some glaciers in the Himalayas are retreating abnormally because of the global warming.

affects women differently because of unequal and differential access to economic opportunities. In natural disasters female mortality outnumbers males. As an example, women accounted for 90 percent of the deaths in the 1991 cyclone in Bangladesh. Urban slum dwellers who subsist on the economic margins of cities have poor access to basic amenities and are usually the first to suffer from climate-related damages to assets and lives. Nearly half the indigenous peoples in the world, around 100 million, live in South Asia. Their dependence on forests makes them especially vulnerable to climate-induced changes in natural resource productivity.

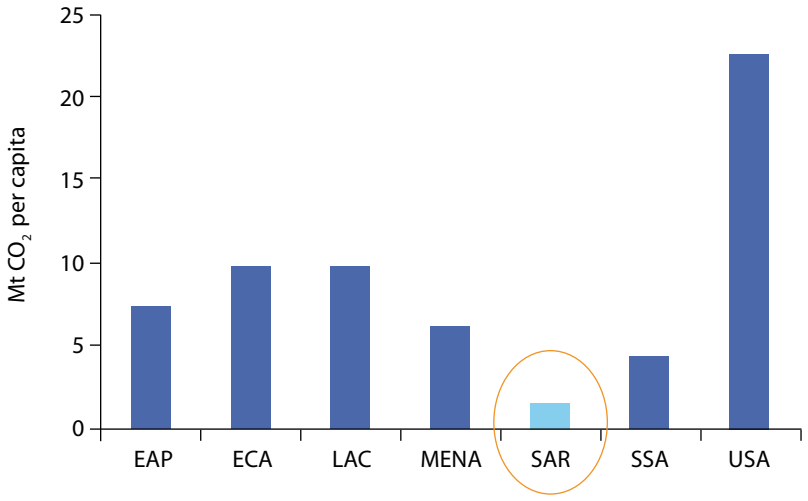
A further cause of concern is the likelihood of climate refugees. South Asia's population is large and growing rapidly; almost any perturbations to the environment will be cause for dislocation. Displacement may be the result of extreme weather events, such as the monsoon floods that displaced more than 20 million people in Bangladesh, India, and Nepal in the summer of 2007, or of sea-level rise. People displaced internally or across borders are vulnerable to poverty impacts that can be irreversible.

South Asia's GHG Footprint

While vulnerability to climate change is high in South Asia, the region has also emerged as a significant contributor to GHG emissions. High economic growth has fueled an insatiable thirst for energy. Rising energy demand is driven by urbanization, industrialization, and prosperity, all of which are part of a broader process of development that is lifting millions out of poverty. However, increased energy consumption has been accompanied by rising GHG emissions. On average, emissions have risen at about 3.3 percent annually since 1990—more rapidly than in any other region of the world, except the Middle East. Total emissions exceed 2.5 billion tons of CO_2 equivalents. However, per capita emissions of the region are still extremely low by international standards—less than one-fifth of the developed countries (Figure 3.8).

As the region strives to meet its development goals, the potential for further growth in emissions is enormous. More than 400 million people in India alone have no access to electricity. How South Asia meets the legitimate demands for energy and economic prosperity will have

Figure 3.8 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

USA: United States of America

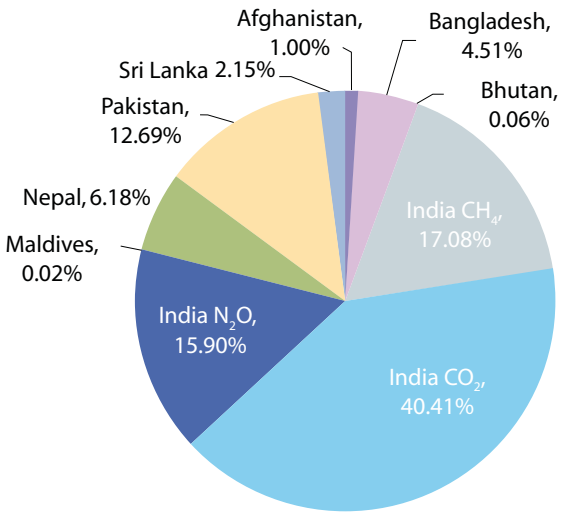
Source: WRI 2009 and World Bank 2009

far-reaching consequences on global GHG emissions. Growth typically spurs emissions in rough proportion to the income in generates.[31] Hence, South Asia like the rest of the world faces an enormous challenge to sustain its growth while addressing global warming.

Reflecting the size of its economy, population and territory, India remains the largest contributor to GHGs in the region. (See Figure 3.9.) However, in terms of emissions per unit of GDP (measured either by purchasing-power parity [PPP] or nominal exchange rates) India remains a low-intensity producer of CO_2 emissions. India's energy intensity of GDP has declined from 0.3 kilograms of oil equivalent (kgoe) in GDP PPP terms in 1972 to 0.19 kgoe in 2003—equivalent to Germany and other energy-efficient economies. This suggests considerable success in decoupling the energy-GDP link at an earlier stage of development than has been achieved in other economies.[32] A recent study suggests that India has successfully offset about 30 percent of its growth- and population-related emissions through improvements in efficiency and changes in economic structure and fuel mix.[33] Importantly, per capita emissions in India are among the lowest in the world, while per capita energy consumption stands at about half the developing country average.[34]

In South Asia energy, industry, agriculture, and to a lesser extent transport are the key contributors to GHGs. (See Table 3.1). The sources of emissions vary substantially across the region. 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 3.9 Greenhouse Gas Contributions by Country in South Asia, 2000



Source: WRI 2009.

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

Transport-related emissions across the region are typically low but could rise rapidly with greater prosperity and sustained economic growth. In many other regions deforestation is an important driver of GHG emissions. By contrast, the forest boundaries in most other South Asian countries (with a few exceptions) have largely stabilized

Michael Foley/World Bank

[31] Globally, a 1 percent increase in per capita income has induced—on average—a 1 percent increase in GHG emissions.

[32] Confederation of Indian Industry 2008.

[33] World Bank 2007a.

[34] IEA Electricity Access Index.

as a result of high rates of forest conversion to agricultural land in earlier decades. However, there remain concerns that the quality of forest stock (i.e., forest density) is declining and hence the carbon sequestration potential of forests could be falling due to unsustainable management practices.

a. **Energy:** Coal is the backbone of the energy sector and is expected to remain the dominant fuel that will power the economies of South Asia. India has the third-largest stock of proven coal reserves in the world, after the United States and China. Strategies to lower emissions by diversifying into cleaner sources of power are constrained by energy resources. India, the largest energy consumer in the region, is not well endowed with reserves of cleaner fuels such as oil, gas, and uranium.[35] Hydropower potential is significant and large in absolute terms (150,000 megawatts) but small compared to the country's future energy needs.[36] There are considerable and untapped possibilities for importing hydropower from Nepal and Bhutan and wind power from Sri Lanka, but there remain difficulties in establishing transboundary energy trade agreements. Based on oil prices during recent decades, the cost advantage of coal and the relative security of the fuel supply, Bangladesh, Pakistan, and Sri Lanka likely will find coal emerge as the front-running fuel for incremental power generation. For Pakistan, the alternative to coal is natural gas imported from its oil-rich neighbors in the Middle East and Central Asia. Pakistan shares a land border with the world's second-largest holder of gas reserves, Iran. In Sri Lanka, the alternative source of supply would be imported liquefied natural gas. However, plans for a massive expansion of coal-fired energy are well advanced, so the prospect of reversing that decision may not be feasible, though little consideration appears to have been given to the health and environmental implications.

b. **Industry:** Industry remains another major contributor, accounting for about 15 percent of GHG emissions. Much of the industrial output is from small- and medium-scale enterprises that utilize outdated and inefficient technologies and processes. There is enormous scope to improve the efficiency and reduce the intensity of energy systems, but there are also considerable challenges in reaching the sector because of the scale and diversity of enterprises and limited financial and technical capacity.

c. **Transport:** South Asia's emissions from transport currently are relatively low but likely to increase rapidly. With rising household incomes and the availability of cheaper vehicles, transport demand is projected to escalate. In India alone the total vehicle stock increased fourfold from 19 million in 1990 to 73 million in 2004.[37] There is every reason to expect this trend to continue with the domestic auto industry predicting car sales to increase by 10 percent per annum for the next two decades (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.

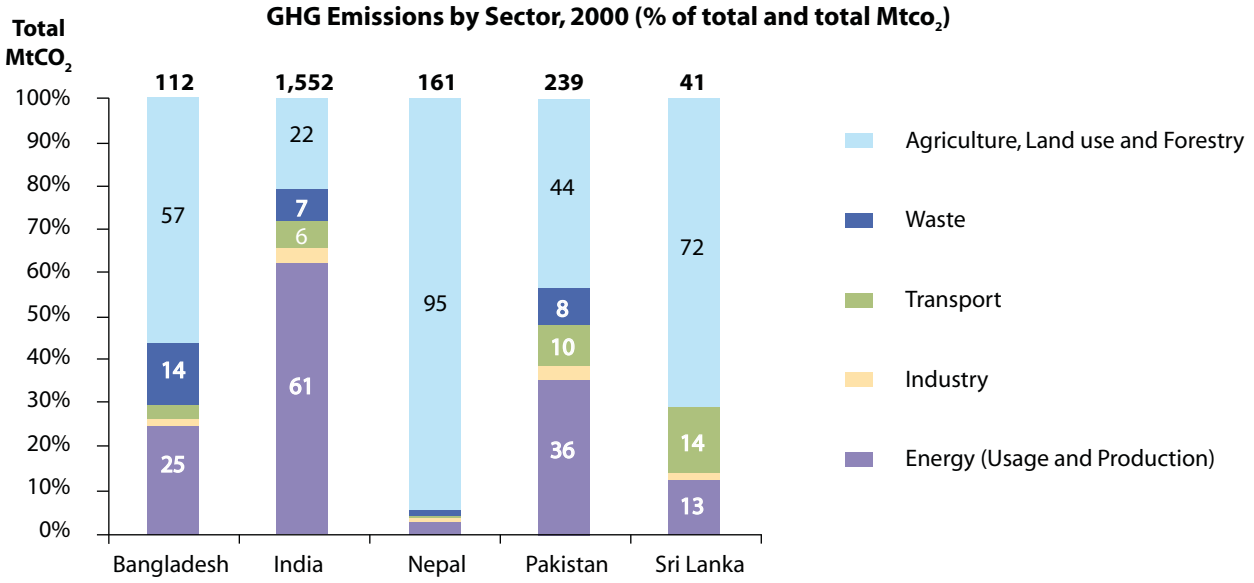
d. **Agriculture:** Methane emissions primarily from rice cultivation and livestock are the principal GHG emissions from agriculture

[35] Oil reserves are 789 million tones of oil equivalent and gas reserves are 1,101 million tones of oil equivalent. (Government of India, Planning Commission 2006).

[36] More precisely, the Government if India's *Integrated Energy Policy* (2006) indicates that with 8 percent growth 150,000 megawatts of hydropower would account for about 5 percent of the country's energy needs by 2030. (Government of India, Planning Commission 2006).

[37] Excluding two- and three-wheelers, there are currently 13 vehicles per 1,000 people in India, while in Japan the ratio is 600 vehicles per 1,000 population. The scope for expansion of the fleet size is thus enormous. The Energy and Resources Institute of India (TERI) cited in Bose and Spurling. 2005.

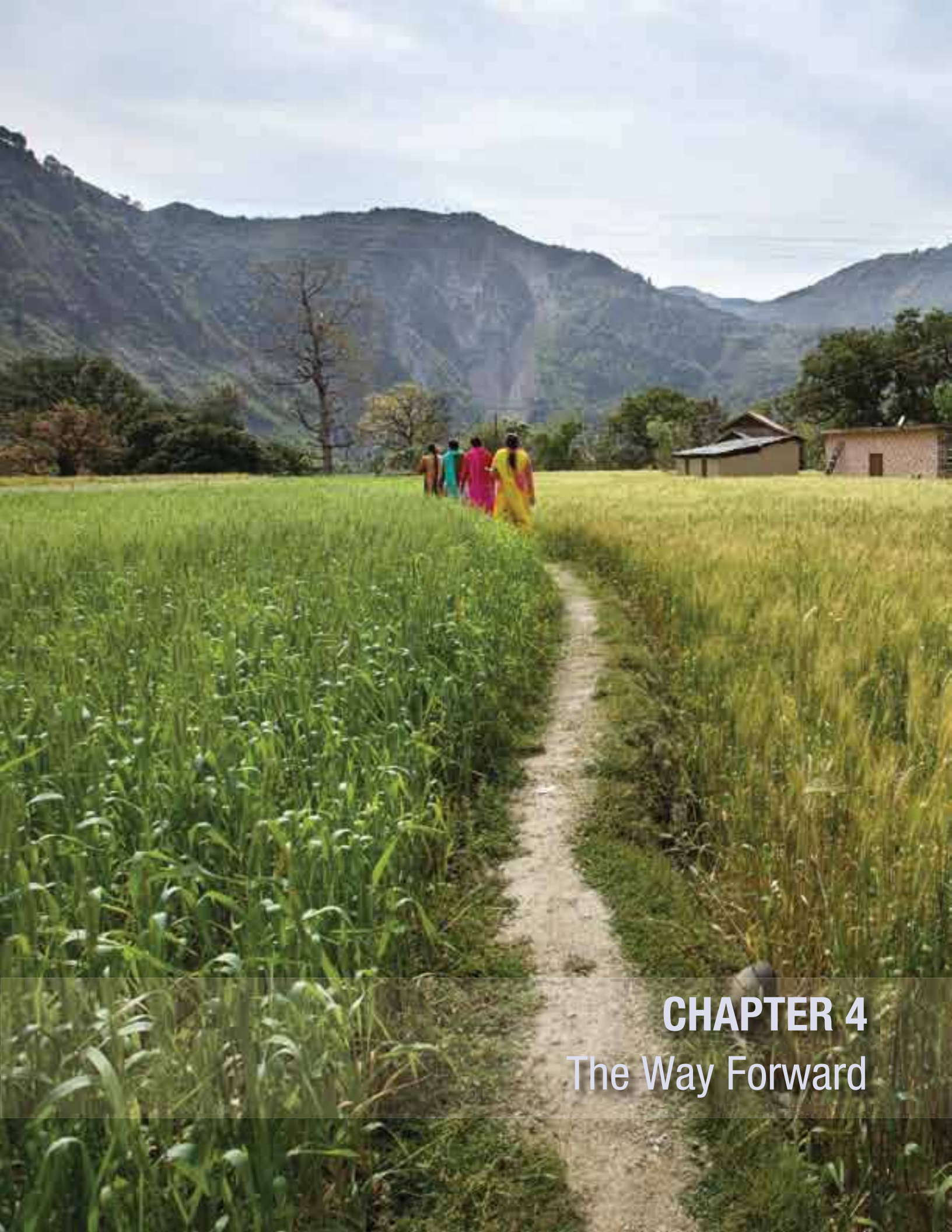
Figure 3.10 Contributions to Greenhouse Gas Emissions by Sector and Country in South Asia



Source: WRI 2009

in South Asia. Together these account for about 25 percent of GHG emissions in India and about 40 percent of emissions in Bangladesh and Pakistan. The major source of agricultural emissions is from flood irrigation of rice. It is important to note that the per hectare emissions from rice cultivation in India (and perhaps elsewhere in South Asia) are approximately 20–30 percent less than the global average. This reflects the special features of the South Asian agricultural landscape: poor soils, low levels of chemical application, the type of rice cultivars used, and the planting regimes.

The following chapter identifies the potential role of the World Bank in helping countries meet their development priorities under climate constraints.



CHAPTER 4
The Way Forward

CHAPTER 4
The Way Forward

Climate change is already a development reality in South Asia. Existing concerns about food security, water scarcity, and energy are made all the more difficult by climate risks that will challenge the goals of inclusive and environmentally sustainable economic growth. Development under climate constraints demands a dual approach. Adaptation is necessary to limit the damage caused by climate change. It enables communities to preempt and manage climate risks and allows governments to protect and "climate-proof" high value assets and infrastructure. Mitigation is also vital since no amount of adaptation planning can protect economies from the potentially catastrophic impacts of climate change. A key to a sound climate-change approach will be to strengthen the knowledge and capacity of institutions that currently manage climate-sensitive assets and natural resources. Recognizing that industrialized countries have contributed most to the existing stock of emissions, there is a broad consensus that developed countries would need to take the lead and shoulder the financial burden of mitigation actions in the near term.[38] However, there also remain wide opportunities for developing countries to participate in emission stabilization in ways that generate win-wins and benefit national development goals.

Role of the World Bank

The World Bank, with its development mandate, has an important role to play in supporting South Asian countries in developing under climate constraints. 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.

Addressing the climate-change challenge must include adaptation, to address the inevitable, and mitigation, to prevent the avoidable. The adaptation dimension is closely linked to the development mission of the Bank. The Bank is therefore well positioned to assist its partners in building economic resilience in order to protect development from climate risks. The Bank also has a large presence in renewable energy, energy efficiency, the water sector, and institutional reform. The Bank can therefore play a key role in facilitating a global transition to low-carbon growth economies in ways that promote sustainable

[38] At the time of writing, the turbulence in financial markets remains a major concern and source of uncertainty.

development and economic progress. There are a suite of instruments available to address the climate challenge. These include knowledge products, technical assistance, and policy advice, as well as investments. Subsequent chapters address this issue in greater detail.

Building country ownership, capacity, and awareness is the key to tackling the climate-change problem. The resources available for climate change are limited, while the region is a large player whose performance (on both emission stabilization and adaptation) 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 activities to be effective, solution must include building partnerships to promote country ownership of climate-change challenges. This calls for tailored approaches to deepen knowledge and institutional awareness so that climate risks are incorporated in country development policies, plans, and programs. It also requires high-impact investments that would have catalytic effects. Strengthening the knowledge base and institutional capacity is especially significant in this context, given that most measures must be guided by government policies.

Michael Foley/World Bank

Adaptation in South Asia

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. Looking to the future, the scale of these impacts will be contingent upon global mitigation efforts undertaken in the next few decades. Delayed or limited emission stabilization will necessitate considerably greater investment in risk management and climate-change adaptation. These uncertainties need to be factored into the development of adaptation strategies and financing plans. In some respects the risks posed by climate change are one of degree—more intense floods, more frequent droughts, or a greater incidence of climate-sensitive diseases. The policies and institutions that enable South Asian countries to cope with these risks today will build resilience in addressing future risks. Simultaneously, climate change is also predicted to bring new and unprecedented problems, such as those associated with sea-level rise and melting of some glaciers. This will call for building new policies to prepare for the potential adverse impacts. However, given 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 challenge of climate change. In many cases institutions will be considerably challenged by the crisis of climate change, in particular where structures are highly fragmented, such as for water resources, and where technical capacity is limited. In all South Asian countries, institutional responsibility for climate change is vested in the environment sector, but the actions and responses that are needed are typically cross-sectoral. There is often limited understanding of climate-change-related problems in sectoral ministries and public sector companies, so an investment in knowledge is crucial.

Climate policies in South Asia will need to be tailored to specific risks and country development

priorities. The projected impacts of climate change in South Asia will be varied and heterogeneous, suggesting that there are no simple blueprints for successful climate-change adaptation. Responses will need to be customized to specific risks. Accordingly, an evolutionary approach is needed to fit individual circumstances. The focus would need to vary depending on country risks, needs, demands, and institutional structures. Recognizing the need for flexibility, the South Asia adaptation priorities could include the following:

a. **Investment in knowledge:** In a situation of uncertainty, knowledge has high value, and which makes the case for vigorous investment in information and better understanding. Adaptation to climate change is analogous to many other forms of risk management. It requires an assessment of possible threats and opportunities arising from climate variability and incorporation of the outcomes of such assessments into policy through the appropriate mechanisms. The challenge is that climate science is imperfect and there is often little reliable information on the path of future climate risks and their likely damages, and in particular if these are regional or local in nature.

b. **A "no-regrets" approach:** No-regrets approaches build resilience to climate risks while generating additional co-benefits. Faced with uncertainty about future risks, no-regrets policies provide an approach to hedging against climate risks. Issues such as irrigation supplies, health care, infrastructure, agricultural technology, disaster preparedness, and habitat protection lend themselves to no-regrets adaptation interventions that simultaneously deliver climate resilience and address current development needs.

c. **A focus on the poor:** The most vulnerable people in developing countries are the poor in the developing countries, who have limited resources and whose assets and livelihoods are exposed to climate-sensitive factors. The poor are also most often employed in sectors such as agriculture that are exposed to high climate risks. Building resilience of these groups to current climate risks is a difficult challenge given their general lack of representation in various institutions, but one that would generate immediate development dividends as well as reduce future climate vulnerability.

d. **Regional cooperation to address common threats:** The most severe climate threats (such as glacier retreat and sea-level rise) transcend national boundaries. Finding effective solutions for flood control, irrigation, and river transport will require cooperation between upper and lower riparian countries. This calls for coordinated solutions to jointly address shared problems. Simultaneously, effective regional cooperation through energy trade can also assist in lowering emissions.

e. **The integrity of environmental services:** Recognizing that climate change is a consequence of damaged and diminished ecoservices, remedial measures need to be aimed at protecting and restoring ecosystem integrity. Indeed, maintaining ecosystem integrity can provide a cost-effective way of building climate resilience and providing a buffer against climate impacts.

Low-carbon Development in South Asia

With a large proportion of South Asia's population living below the poverty line, any low-carbon growth approach must be consistent with the region's development objectives of improving living standards and incomes. Fortunately, opportunities do exist to harness *win-wins* by focusing on measures that generate significant co-benefits such as improvements in energy and economic efficiency, reduction in local pollutants, and improvements in natural resource management.

The Bank's South Asia region has initiated a strong dialogue and a work program to realize these multiple benefits and to expand its activities. There are three key pillars that could guide low-carbon development and growth:

a. **Win-win policies:** Such policies not only provide global benefits in reducing GHGs but also pay for themselves in domestic benefits such as reduced fuel expenditure, energy efficiency, greater energy security, and improved air quality. If win-win policies were easy to implement, they would have long since been put in place. But they are often impeded by regulatory barriers, financial constraints, coordination problems, institutional bottlenecks, or market failures. Some (IEA 2006; Farrell et al. 2008) see tremendous untapped opportunities for win-win policies and argue that the mitigation challenges can be largely achieved with such structural realignments. But others are skeptical, emphasizing the formidable policy and political economy obstacles that would need to be overcome. The Bank, with its long global experience in addressing institutional and policy hurdles, is well positioned to assist countries harness these opportunities.

b. **Support for low-carbon growth activities:** All South Asian countries would need to be compensated for the additional costs of mitigation actions that go beyond their development objectives. This approach underlies the UNFCCC principle of "common but differentiated responsibilities." It recognizes that current climate risks are the consequence of past actions and that there is a need for ensuring equal and fair access to the global atmospheric commons. A corollary is that current development needs would need to remain the overarching priority in South Asia.

c. **Accelerated technology deployment:** Wider adoption of new, clean technologies is expensive and risky, but with further research and adoption, they can become more economical and accessible. Development, deployment, and diffusion of affordable technology are critical to enabling developing countries to meet the challenges of climate change. Hence the transfer of technology and intellectual property rights regimes will be pivotal in determining the success of any global measures to stabilize GHGs. The World Bank can play a supportive and catalytic role in this process through technical assistance.

Tables 4.5 and 4.6 (located at the end of this chapter) provide a summary of the main climate risks and priority responses across the South Asia region—by sector and country. The Bank has at its disposal a wide range of instruments that include knowledge partnerships and capacity building (including climate risk assessments, assistance with global negotiations where required, reports, and technical support) and investments. Consistent with its mandate the focus will be on the development impacts of climate change. The risks and responses suggest the need for the development of a climate-sensitive approach that builds on many aspects of the current portfolio of activities that already contain dimensions related to both adaptation and

Michael Foley/World Bank

mitigation. Some existing activities would need to be further enhanced to address climate challenges, demands, and needs. To be effective the approach must aim to build country capacity and ownership of the climate-change challenge.

In a resource-constrained environment there will be a need to leverage funds effectively to achieve transformational impacts. Full use will need to be made of the evolving financial instruments, such as the Climate Investment Funds and their components, in addition to other global resources such as 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) and other agreements. The following section provides an overview of available financial resources.

Financing Climate Adaptation and Mitigation

Climate change represents an unprecedented development challenge, and 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.[39] Responding to the climate challenge will require additional financing that should *complement rather than compete* with investments required for development. The global financial architecture would likely be negotiated in a forum such as the UNFCCC, and until this occurs it will be difficult to cover the financial gap.

Most South Asian countries already spend a significant proportion of their development budgets to address climate-related risks. In India

Box 4.1 Can Regional Cooperation Reduce Climate Vulnerabilities of South Asia?

During the 1990s, South Asia's economies grew rapidly at an average of 6 percent annually. The growth further accelerated to 6.5 percent from 2000 to 2007. Rapid growth has been instrumental in reducing poverty in South Asia. Progress has also improved human development and social indicators. South Asia is the least integrated region in the world and has the potential to grow further if the region is integrated.

South Asia would probably gain most from regional cooperation in water, energy, and climate. Regional cooperation can be a powerful tool for increasing growth, reducing inequality, increasing energy trade, and reducing vulnerabilities for the poor. By reducing vulnerability, regional cooperation can be helpful in lowering income inequality.

The melting of some Himalayan glaciers leading to the disastrous prospect of reduced water availability in the South Asian rivers, the frequency of floods, and the evidence of rising sea level necessitates collective action for managing and reducing the vulnerability to climate change.

Actions at the national level cannot provide sustainable solutions since upstream flows from Afghanistan, Nepal, and parts of India impact Bangladesh, most of India, and Pakistan. Finding solutions for flood control, irrigation, and river transport will require cooperation with upstream countries. Thus, cross-border cooperation on water among India, Bangladesh, and Nepal offers a long-term solution to flood mitigation. There are similar benefits to water cooperation between India and Pakistan and between Pakistan and Afghanistan. The success of the Indus Water Treaty between Pakistan and India has already demonstrated that cooperation that benefits people can withstand all political obstacles.

What are the key constraining factors? First and foremost is the prevalence of a number of regional differences and priorities. Closer cooperation in climate-related issues and trade could be a catalyst for resolving political and social differences. Given the magnitude of climate-related events, it is critical that countries move toward meaningful cooperation rather waiting for all differences to be resolved.

[39] A recent review conducted by the Bank suggests that the available funds for both climate mitigation and adaptation are of the order of US$10 billion, pointing to a deficit in the order of hundreds of billions of US dollars per annum.

Michael Foley/World Bank

for instance, the direct losses from natural disasters are about 2 percent of GDP and perhaps as much as 12 percent of government revenues (World Bank 2003). Climate change is expected to increase the frequency of adverse climate events and raise the costs of development. Though the resources that are currently available to meet the additional costs of climate change are insufficient, South Asian countries will need to prepare to utilize the new funds that are being developed to address climate risks in developing countries. There are also a number of financial instruments that are available to promote low-carbon development. These provide an opportunity to leverage the many untapped opportunities for investment in mitigation that simultaneously deliver other development benefits. The Bank can play an important role in helping South Asian countries access these resources.

Financing the Transition to Low-carbon Economies

The World Bank has pioneered numerous initiatives to ensure that developing countries and economies in transition benefit from international efforts to address climate change. The expansion of the carbon market in recent years

Box 4.2 Lagging Regions and Climate Change

Recent rapid economic growth has been accompanied by rising regional inequality in South Asia. Growing income inequality and imbalances between regions within countries and among the countries could present social and economic problems to more prosperous neighbors as would imbalances within the countries.

India's southern and western states, taking advantage of the global economy, are growing faster than the northern and eastern states. Sri Lanka's western province now contributes more than 50 percent of national GDP. Poverty rates in Pakistan's southern Punjab are twice those in northern Punjab. The disparities are seen even within the fast-growing state of Andhra Pradesh in India. The dismal prospects of rural economies that depend on agriculture remain the primary factor behind this rising inequality in South Asia. Unless the lagging regions participate in the growth, not much will change for millions of poor people.

The problem of inequality is, however, a more complex challenge. Growth acceleration in the lagging regions might help reduce inequality, but this is only a part of the larger task of making growth more inclusive. The large concentration of poor in the lagging regions suggest public policy must focus on raising growth and improving human development in these lagging regions.

The lagging regions share a number of common vulnerabilities, including a high dependence on natural resources and climate-sensitive sectors of the economy. First and foremost is their vulnerability to natural disasters. South Asia has lost a significant amount of its GDP because of natural disasters, and this impact is particularly harmful because of the region's high population density. This loss has been especially significant in many of the lagging regions of Bangladesh, India, and Pakistan. A second and related vulnerability is resource degradation and, in particular, access to water. Many of the lagging regions are arid and depend on groundwater for irrigation. Unsustainable irrigation will take more of a toll if droughts become more frequent because of climate change. Frequent water shortages and intermittent floods create serious challenges to maintaining the income level of large numbers of poor people. With melting of some glaciers, flood risks would increase in the near future, and it is lagging states such as Bihar and Jharkand in India, and Nepal and Bangladesh that will bear the brunt of these major climatic changes. All of this suggests that building climate resilience is an important part of any approach to igniting growth in the lagging regions of South Asia.

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 metric tons of carbon dioxide equivalent in 2007, amounting to trades of US$64 billion. About 20 percent of these carbon reductions were generated from developing countries through the Clean Development Mechanism (CDM) under the Kyoto Protocol—mainly from China, India and Brazil—and in projects involving renewable energy development and energy efficiency. A similar mechanism focused on transitional economies, termed Joint Implementation (JI), has focused on emission reductions in economies in transition, with Russia, Ukraine, and Bulgaria being the most important suppliers. Under current projections, the market-based mechanisms (CDM and JI) would contribute 20 percent of the total demand for emission reductions by 2012. Since their inception, the carbon markets have mobilized thousands of entrepreneurs in the private and public sectors, as well as in communities throughout the developing world.

The Carbon Finance Unit (CFU) in the Bank has developed numerous funds to assist project-based emission reductions in developing countries. The CFU has been an important catalyst in the formation of the carbon markets, by benchmarking carbon assets, and developing projects in new sectors. Funds are generated from the contributions of governments and companies in Organisation for Economic Co-operation and Development (OECD) countries and are used to purchase project-based GHG reductions in developing countries and economies in transitions. Carbon finance provides a stream of revenue for these countries, raising the bankability of projects and reducing the risks of commercial lending and grant finance. Hence, it enables the leveraging of new private and public investments into projects that mitigate climate change at the same time contributing to sustainable development. Table 4.1 lists the new sources of carbon finance that have been supported by the Bank for mitigation initiatives.

A number of recent developments are expected to contribute to the evolution and transformation of the carbon markets over the next few years, in particular for emission reductions originating in developing countries. These include (i) the second commitment period under the Kyoto Protocol (post-2012), which will likely include mechanisms to scale up the CDM and JI and provide more flexible operational procedures and eligibility requirements; (ii) the European Union is likely to extend the European Union Emissions Trading Scheme beyond 2012 and could include linkages to the CDM and JI, thereby expanding the size and scope of the market; and (iii) the growing demand for carbon offsets from the voluntary market.

Considering these rapidly evolving conditions, the World Bank's Board of Directors has approved the launch of two new carbon facilities in September 2007. The first is the Carbon Partnership Facility, which will purchase emissions reductions for at least 10 years beyond 2012 in an effort to promote a shift toward investments in long-term, low-carbon technologies where otherwise GHG emissions would be locked in for decades to come. Recognizing the importance of forests as a carbon sink, a Forest Carbon Partnership Facility is dedicated to reducing emissions from deforestation and degradation. This initiative is aimed at setting the stage for future systems for performance-based payments that would provide incentives to slow deforestation and degradation. Consistent with the Bank's role to further develop the carbon market, these two facilities are based on the need to support long-term investments in an uncertain market environment, possibly spanning several market cycles. "Learning by doing" approaches will be an essential aspect of these facilities, as the carbon market moves from individual projects to programmatic approaches, including methodologies needed for such approaches.

Table 4.1 Low-carbon Growth Financing

Carbon Finance Fund	Description	Funds (US$ millions)
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	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.	Currently allowable upper limit 5 billion euros
Clean Technology Fund	Designed to promote transformational investments in low-carbon technologies.	5,000

A capacity-building and technical assistance program has been established to enhance the capacity and expertise of developing countries in engaging in the GHG market. The CF-Assist is a capacity building and technical assistance program that supports project identification and preparation for GHG emission reduction and sequestration. The program is undertaken in three phases with clearly defined objectives. The first phase is aimed at establishing focal points, identifying potential CDM and JI opportunities, and training. In the second phase, technical assistance is provided for development of project design documents, marketing of projects to carbon buyers, identification of industry association or intermediary, integration of carbon finance into investment promotion strategies, and engagement of financial sector to promote integration of carbon finance in lending strategies.

The Global Environment Facility (GEF) has also provided some assistance for development of clean

Box 4.3 Carbon Partnership Facility

The Carbon Partnership Facility (CPF, or the Facility) promotes GHG emission reductions (ERs) on a larger scale through the provision of carbon finance for long-term investments that is designed to scale up the delivery of carbon finance through programmatic and sectoral initiatives and methodologies. Moving to programmatic and sectoral and country-wide approaches is a response to the limitations of the project-based Clean Development Mechanism and Joint Implementation initiatives that have high transaction costs. Ultimately, the Facility aims to contribute to a transformation of economic activities in energy, energy efficiency, waste management, oil and gas, transportation, and urban sectors of Bank client countries in the direction of less carbon-intensive activities.

The CPF will establish partnerships to sell and purchase ERs from long-term programs beyond 2012 and support GHG emissions mitigation programs (ER Programs). Unlike the traditional carbon funds administered by the Bank whereby the Bank acts as trustee, the governance structure and trustee role of the CPF will include developing country governments and companies as sellers. This partnership approach reflects the sharing of risk between potential sellers and buyers of ER Programs during a period when the regulatory environment beyond the first Kyoto Protocol is uncertain and the global carbon market remains fragmented.

The CPF will comprise two trust funds: the Carbon Asset Development Fund (CADF) and the Carbon Fund. The CADF will hold funds generated from fee payments from buyer participants, donor contributions as well as investment income. The Carbon Fund will use financial contributions from buyer participants (governments or public and eligible private entities) to pay for ERs as they are received. The Carbon Fund will have funding tranches, with a discrete set of buyer participants and portfolio criteria. The portfolio criteria may cover several sectors and technologies or be more narrowly focused. Seller participants can participate in the facility by putting forward ER Programs allocated by the Trustee to one or more of the Carbon Fund tranches.

The proposed CPF is an important and integral part of the Bank's strategic framework on climate change that is currently under preparation and is expected to complement the Climate Investment Funds, notably the Clean Technology Fund.

Source: Partnership Review Note: Carbon Partnership Facility, The World Bank, Carbon Finance Unit

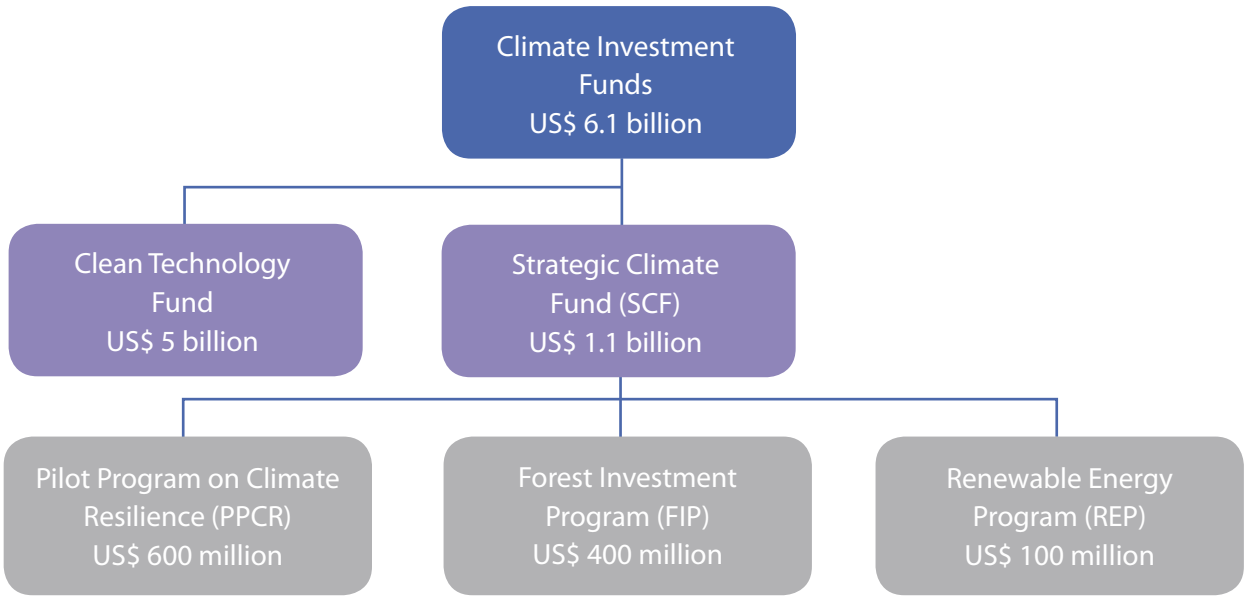
renewable energy and improving energy efficiency in developing countries. The GEF-financed energy projects in renewable energy and energy efficiency approved in 2003–2006 are expected to directly reduce emissions of greenhouse gases by 388 million tons over the project lifetime.

The Climate Investment Funds are the most recent source of funding that provide an opportunity for increased assistance to developing countries for promoting climate resilience and low-carbon growth. When they signed the UNFCCC, governments agreed to help developing countries meet the climate-change challenge through additional resources for both adaptation and mitigation. The Climate Investment Funds represent a major global effort for financing mitigation and adaptation efforts in developing countries in advance of the global financial architecture to be developed under the UNFCCC. Two trust funds have been established under the Climate Investment Funds: the Clean Technology Fund and the Strategic Climate Fund (Figure 4.2). The Clean Technology Fund is designed to support projects and programs in developing countries that contribute to the demonstration, deployment, and transfer of low-carbon technologies that can have significant potential for long-term greenhouse gas savings. The Strategic Climate Fund, on the other hand, is broader in scope and serves as an overarching fund for various programs to test innovative approaches to climate change, with an emphasis on adaptation. In September 2008, about US$6.1 billion had been pledged for this investment. There are also plans to establish a Forest Investment Program and a Scaling-Up Renewable Energy Program under the Strategic Climate Fund in the coming months. Designed as an interim measure, the Climate Investment Funds include specific sunset clauses.

Financing Options for Climate Adaptation

The Global Environmental Facility has been the main source of grant and concessional funding for adaptation projects. The initial phases of GEF financing covered vulnerability and adaptation assessments and capacity-building projects.

Figure 4.1 Structure of the Climate Investment Funds



Pilot adaptation projects are funded through the Strategic Priority on Adaptation (SPA), a US$50 million GEF trust fund. Other GEF resources include the Least Developed Countries Fund (LDCF), which is targeted to 49 least-developing countries, and the Special Climate Change Fund (SCCF), which is accessible to all developing countries (Table 4.2). These funds integrate adaptation measures into development practices. Since its inception, the GEF has disbursed about US$120 million for "national communications," of which a significant amount has been allocated to vulnerability and adaptation

Table 4.2 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

assessments. In addition, about US$28 million has been provided to support capacity building, and about US$78 Million worth of projects have been approved under SPA, LDCF, and SCCF. While these funds have delivered resources for filling information gaps and capacity building, their magnitude has been insufficient to catalyze robust adaptation initiatives on the ground. South Asia's share in these resources has been limited with only three projects approved amounting to about US$8 million (Table 4.3).

Future funding for adaptation is also being established through a special Adaptation Fund. The structure, governance, and management of this fund are still under negotiation. The fund is to be managed by an independent board with representation from the five UN regions. It is to be financed through a 2 percent levy on CDM projects. Estimates of the size of this fund vary and suggest that the levy could translate from about US$100 million to US$5 billion depending upon the demand for emission-reduction credits. The sustainability of this fund clearly depends on the continuity of the CDM and the development of the carbon market. Existing estimates of adaptation needs suggest that the expected level of funding will be insufficient to cover future costs of adaptation. Financing adaptation through a tax on CDM implies that adaptation is being encouraged by making mitigation more expensive and hence less attractive. The extent of substitution this would promote is unclear in the absence of data on the relevant elasticities of substitution. Economic reasoning would suggest it would be more consistent and effective to impose a levy on emissions (the cause of the problem) rather than mitigation (a solution to the problem).

The Global Facility for Disaster Reduction and Recovery (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. The GFDRR aims to mainstream disaster reduction and climate-change adaptation in country development strategies to reduce vulnerabilities to natural hazards. It funds disaster risk assessments, risk mitigation policies and strategies, preparation of disaster prevention projects, and additional financing for recovery. Its program is undertaken in three tracks representing global, regional, and country-level engagements. Track I supports annual work programs of the International Strategy for Disaster Reduction to enhance global and regional advocacy,

Table 4.3 GEF Projects under the New Climate Change Funds

Country	Project Title	Agency/Fund	Project Grant (US$ approved)	Co-financing Total (US$)
Sri Lanka	Participatory Coastal Zone Restoration and Sustainable Management in Eastern Province of Post Tsunami Sri Lanka	IFAD[40]/ Strategic Priority on Adaptation	1,919,000	7,569,000
Bangladesh	Community-based Adaptation to Climate Change through Coastal Afforestation	UNDP/ Least Developed Countries Fund	3,000,000	6,080,000
Bhutan	Reduce Climate Change- Induced Risks and Vulnerabilities from Glacial Lake Outbursts in Punakha-Wangdi and Chamkhar Valley	UNDP/ Least Developed Countries Fund	3,455,000	3,469,000

[40] International Fund for Agricultural Development.

partnerships, and knowledge management in disaster risk reduction. Track II provides ex ante support through three-year technical assistance programs to improve investments in risk reduction, institutional development, risk transfer mechanisms, and adaptation to climate change. Track III is geared toward enhancing the mobilization of international assistance for disaster recovery and toward supporting the accelerated disaster recovery of low-income countries. Activities supported by GFDRR in South Asia amounted to US$4.3 million (Table 4.4).

Recognizing the need to address the funding gap, the Bank has been working with bilateral donors and other groups to establish country partnerships to mobilize additional resources. The most recent example is the DfID-financed[41] Bangladesh Climate Change Trust Fund, which provides grant resources for urgent adaptation needs. In the short term, greater effort will need to be devoted to build partnerships with donors and other groups.

What is clear is that the current framework for climate-change financing is provisional and the funds available are not commensurate to 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.

The International Finance Corporation also supports the private sector in transitioning to a lower-carbon growth path and in adapting their business operations to climate risks.

Conclusions and Strategic Approach

Climate change has made poverty reduction and development more challenging. Recognizing these problems, the *Strategic Framework for Development and Climate Change* (2008) defines

Table 4.4 GFDRR Projects in South Asia under Track II

Proposal Title	Country	Total Cost (US$)
2nd Asian Conference on Disaster Reduction	India	75,000
Development of Lessons Learned Reports from Gujarat Emergency Reconstruction Project	India	350,000
Implementation Support for High-Priority Disaster Risk Mitigation Program in India	India	400,000
India Crop Insurance: Developing Market-based Products	India	668,250
Bangladesh: Agricultural Risk Insurance Feasibility Study	Bangladesh	296,000
Climate Change and Future Flood Risks	Bangladesh	370,000
Improving Bangladesh's Response and Recovery Activities	Bangladesh	230,000
Building Capacity to Effectively Deliver Safety Nets in Post-disaster Situations in Pakistan	Pakistan	290,000
Communicating Results Achieved and Lessons Learnt	Pakistan	250,000
Improving Sri Lanka's Response and Recovery in the Aftermath of Natural Disaster	Sri Lanka	230,000
Hazard Risk Management Program: Nepal	Nepal	914,000
Nepal: Agricultural Insurance Feasibility Study	Nepal	188,000

[41] Department for International Development (DFID), United Kingdom.

Box 4.4 IFC's Support to Climate Mitigation and Adaptation in South Asia

Sustainable Energy Finance and Energy Efficiency

A key impediment to the large-scale adoption of energy efficiency is financing of energy-saving improvements and renewable energy. IFC has two projects under development—one in Sri Lanka and one in Nepal—which have a high level of replication potential.

The Portfolio Approach to Distributed Generation Opportunities in Sri Lanka aims to improve access to cleaner and more reliable sources of energy for underserved populations. The model will develop a framework under which various parties (manufacturers, developers, operating companies, banks, rural communities, etc.) are provided tools (template agreements and contracts, performance standards for equipment, and financing opportunities) to encourage entry into the market while maintaining the quality of service provided, so as to lower transaction costs. The framework is designed to be flexible to address the various local constraints and available energy resources to allow for replication in other countries/regions.

In Nepal, IFC will support three commercial banks to develop a portfolio of energy-efficiency finance projects that they will offer to the Nepalese industry. Energy-intensive industries such as rolling mills, cement, sugar, paper, structural clay, distillery, bakery, rubber, leather, noodle, wool dyeing, and jute would be targeted with tailored financial products for energy efficiency that would enable the companies to reduce their energy consumption, costs, and emissions of GHGs. This effort is also intended to serve as demonstration case in Nepal (and potentially for the region) that will improve awareness and understanding of energy efficiency and build technical capacity among financial institutions to provide energy-efficiency lending services.

Investing in Renewable Energy

While climate change presents a considerable challenge, it also provides the private sector with the opportunity to expand its activities and grow while helping mitigate the risks of climate change and adapt to its impacts. In this context, IFC has a growing portfolio of renewable energy investments that are helping displace coal power generation and reduce GHG emissions. This portfolio includes four hydropower projects (two in Nepal and two in India); a bagasse cogeneration plant at two mills for a large sugar producer in India for a total of 40 megawatts; wind energy investments in two wind farms in India totaling 37 megawatts; and a potential investment in a photovoltaic plant in Tamil Nadu (India).

IFC has helped Indian manufacturer Moser Baer expand into solar photovoltaic (PV) cell and module production. Solar PV is a renewable energy source that is used for electricity production in both stand-alone and grid-connected applications. IFC is also supporting Jain Irrigation, one of the major agribusiness companies in India, in setting up an agricultural waste-based power project as well as helping them define a strategy to become a renewable power sector player in India.

Carbon Finance

IFC's role in the carbon-finance market is to help create a level playing field between emerging market projects and developed country buyers without distorting the market. In South Asia, IFC has successfully concluded emissions reduction purchase agreements with Eco Power, a private developer of small hydropower plants in Sri Lanka with more than 30 megawatts in seven projects and with Indian Hydropower Development Company for small-scale "bundled" projects owned and operated by the latter.

IFC has also recently provided a Carbon Delivery Guarantee for credits from a waste heat recovery project done by Rain CCII Carnon India Limited that reduces the company's dependence on fossil fuels.

As part of the World Bank Group's effort to deepen access to carbon finance, IFC also expects to offer carbon market-related advisory services to its clients, especially municipalities and financial institutions through wholesale aggregation arrangements for energy efficiency savings in lighting, water pumps, etc.

Cleaner Production Assessments

IFC's work in Cleaner Production Assessments supports the adoption of profitable cleaner production initiatives—such as energy efficiency and water conservation and recycling—among IFC's clients, thus setting an example and promoting demand for cleaner technologies. Typically, IFC provides technical assistance to companies in the form of clean production (CP) audits that help identify energy, water, and other type of resource savings, which reduce GHG emissions for client operations as well as improve profitability.

In South Asia, IFC has targeted a high-carbon footprint sector in India (paper and pulp) to conduct CP audits in three companies that will focus on energy and water audits, resource conservation, and GHG estimation. These audits are currently underway and another seven to 10 companies have expressed interest in undertaking CP audits. IFC has also set up a global fast-tracking financing facility called the Cleaner Production Lending Pilot that will enable existing IFC clients to access loans up to US$5 million to implement some of the recommendations from the CP audits.

Cleaner Technologies Program

IFC's Cleaner Technologies investing focuses mainly on supporting small, high-risk ventures with accelerated technology transfer and commercialization of intellectual property. IFC has directly invested in areas of increasing strategic interest, such as the water sector, and it will play a major role in guiding the World Bank Group's work on accelerating clean energy technology innovation. The Cleaner Technologies program typically provides funding ranging from US$200,000 to US$2,000,000 for innovative business initiatives that produce goods and services with environmental benefits. The program's approach going forward is to focus on Asia.

the parameters of the World Bank Group's overall approach to the climate challenge. *South Asia: Shared Views in development and Climate Change* develops responses to the climate challenge in South Asia that are consistent with the paradigm outlined in the *Framework*. The main aim is to help client countries in South Asia catalyze a process that would build climate-resilient economies that grow along a low-carbon trajectory. To achieve this it will be necessary to promote country ownership, fill knowledge gaps, and build institutional and financial capacity. With high levels of poverty and dependence on climate-sensitive sectors of the economy, the challenges are wide ranging, suggesting the need for integrated approaches that transcend sectors and countries. Simultaneously, there are opportunities for low-carbon growth in ways that meet current development needs.

The Bank is one of many players in the global arena of climate change. The Bank's comparative advantage is to help countries address the implications of climate change across its many development challenges: local, national, sectoral, and regional. To this effect, the Bank can use an array of instruments that will lead to a shift in the services that it provides to its clients as they strive for development and poverty reduction while building climate-resilient and low-carbon trajectories. Depending on the various clients' demands, the Bank can offer the following:

- **Climate-specific investments:** The new climate funds such as the Climate Investment Funds, the GEF climate funds, and carbon-finance programs provide the additional resources that are required for climate-specific investments for both adaptation and low carbon growth.
- **Integration of climate considerations in the portfolio:** With client countries spending large sums of money on investments, there is a need to ensure that they get the most sustainable long-term outcomes possible. This includes the consideration of climate-change impacts, e.g., on infrastructure, on ecosystems, and on services such as water supply or health care. The Bank will include climate-change considerations in its investments in order to help clients build climate-resilience and low-carbon trajectories in the investments that would be undertaken anyway and whose quality would be compromised if climate considerations were neglected.
- **Technical assistance for knowledge, research, and capacity building:** With uncertainty and sparse knowledge of climate impacts, there is a clear need to fill critical knowledge gaps in ways that improve decision making and raise awareness. The Bank has already played an important role

with seminal contributions on adaptation to climate change in climate-stressed parts of India and a low-carbon growth study for India. But much more remains to be done to better understand critical climate risks and their economic impacts across the region, as well as to identify low-carbon growth opportunities. Climate change will also challenge existing institutional structures and calls for greater integration of climate risks in development policy, as well as cross-sectoral coordination between countries and government agencies. Technical assistance would therefore need to play a key role for building institutional capacities and defining the architecture for improved climate governance among sectors and countries of the region. With its presence across all countries in South Asia, the Bank can play an especially useful role in catalyzing a regional dialog on the common climate risks and opportunities.

- **Financing and harmonization:** In an environment of resource scarcity there is a need to utilize existing resources effectively, which calls for, among other things, harmonization and building synergies with other development partners. The Bank can play a key role to help countries leverage existing global resources more effectively and coordinate with development partners. The Bank is also a significant player in developing alternative financial modalities and instruments. Climate-specific multidonor trust funds, innovative instruments for risk financing (such as CAT bonds and climate contingent insurance) and "green" bonds are among the many initiatives under various stages of development and application.

The approach is based on the premise of flexibility and allows adjustments as knowledge regarding climate-change effects improves globally and in South Asia. There will also be a need for learning through more integrated approaches that address both the cross-border and the cross-sectoral impacts of climate change. Illustrating the complexity of the challenge, the tables that follow summarize some of the main climate risks by both sector and country. These issues are addressed in greater detail in the following section of this document.

Table 4.5 Summary of Sector Impacts in the Context of Climate Change and Priority Responses

Sectors	Risks	Priority Response
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
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.
Agriculture	• Declining yields of major crops • Agriculture unviable in marginal areas e.g. arid, semi-arid, and coastal (saline intrusion-affected 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, contingent credit schemes) • Irrigation development and increased investment in water harvesting infrastructure at required scales that take account of climate risks • Development of incentives and innovative approaches for rural development to diversify income and buttress against climatic risks
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 nonstructural measures • Catastrophe risk financing or transfers (where needed)
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

Sectors	Risks	Priority Response
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, indigenous populations (IPs) and other vulnerable groups for reducing agricultural dependence • Promotion of self-help groups (SHGs); and enhancing access to microfinance and banking services • Strengthening social capital of vulnerable groups, their access and decision making • Promotion of community-based asset building and sharing of natural resources
Ecosystems and Biodiversity	• Quantitative and qualitative damage upon 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, climate mitigation, adaptation and risk management • Designing and building biodiversity-friendly and climate-resilient infrastructure • Generation of knowledge and capacity
Energy	• Political economy (nonclimate) barriers to developing regional energy trade • Poor quality local coal • Aging and inefficient thermal power generation, high transmission and distribution losses • Inefficient energy use • Poor energy pricing frameworks including underpriced electricity for lift irrigation which can consume up to 20 percent of supplies in some countries	• 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
Transport	• Increase in number of private vehicles and usage per vehicle • Increase in age and efficiency of vehicle fleet • Ongoing deterioration of public transport in cities • Expansion of low-density urban land development which is not friendly to public	• 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

Sectors	Risks	Priority Response
	transport and non-motorized transport • Rail freight competitiveness and efficiency	high-growth, medium-sized cities • Promoting the modal shift to rail transport • Fuel efficiency standards for road vehicles
Urban	• Climate-related damage upon 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 GHG emissions of future urbanization	• Integration of climate adaptation and disaster risk management within the urban climate-change approach • Harnessing mitigation potential in industries such as solid waste, wastewater treatment, energy-efficient buildings and infrastructure • Improving energy-efficient buildings

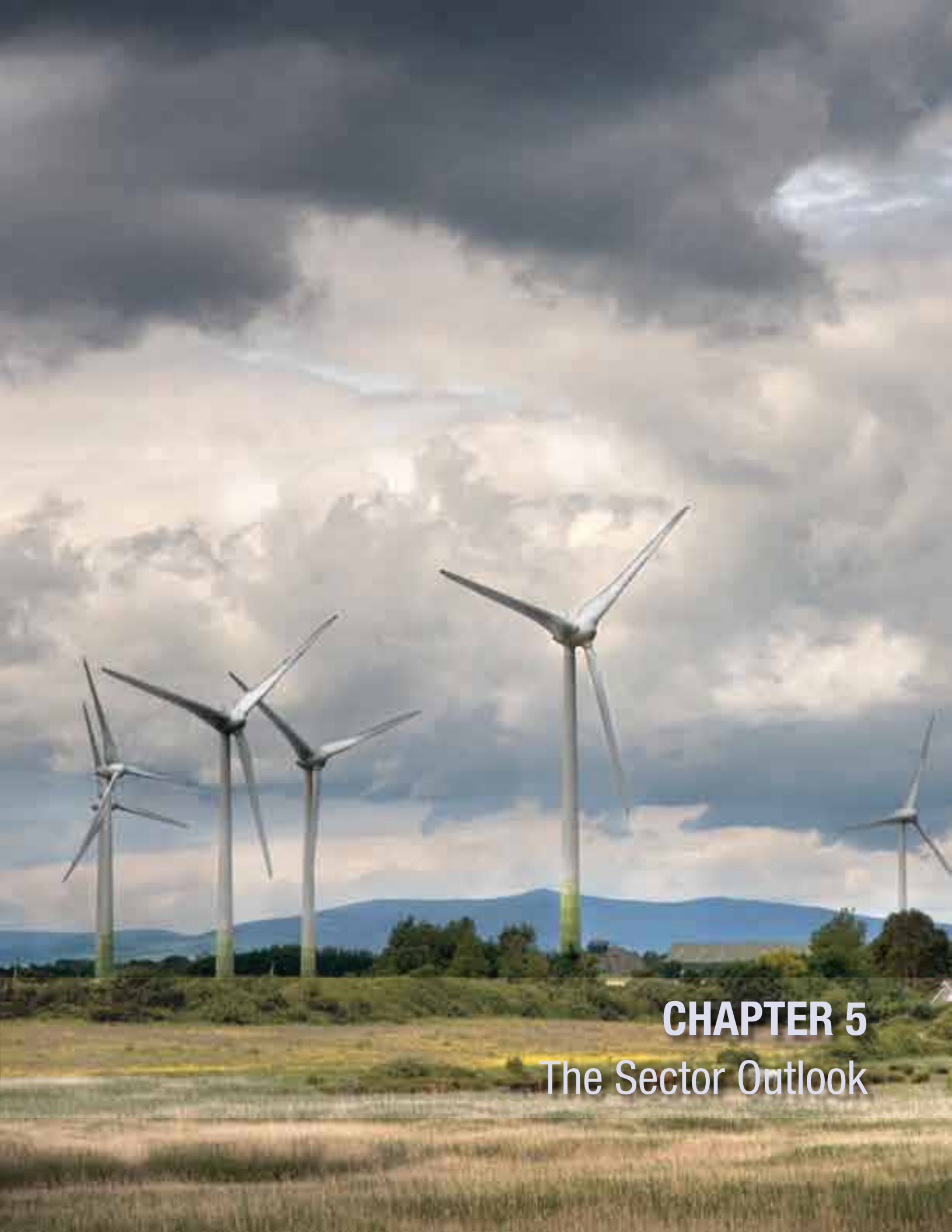
Table 4.6 Possible Risks for Countries

Country	Risks
Afghanistan	*Climate-change Impacts* - Exposure of agriculture (pasture), ecosystems, and water resources to drought and desertification - Flooding from glacial melt and long run vulnerability of depletion of water supplies of glacial-fed rivers - Water and food insecurity, malnutrition, and possible migration and conflict
Bangladesh	*Climate-change Impacts* - Combined impacts of sea-level rise and glacial melt lead to increased incidence of flooding and land loss - Drought in some areas - More intense storm surges - Lower agricultural output through diminished yields and loss of land - Increased incidence of heat-related illnesses, water-borne diseases, poverty, child and infant mortality; lower access to safe water and sanitation and possible migration - Loss of biodiversity in coastal ecosystems; Sunderbans at high risk *Mitigation Issues* - Increased coal dependence (risks of early transition to coal)
Bhutan	*Climate-change Impacts* - Damages from glacial melt - Impact of increased temperature on rangelands and agriculture. - Potential loss of forest biodiversity due to vegetation shift and increased incidence of forest fire due to temperature increase

Country	Risks
India	*Climate-change Impacts* - Exposure of agriculture, water resources, and ecosystems to extreme weather events and more variable precipitation - Impact of glacial melt on water resources quantity, biodiversity, and low-lying agriculture - Impacts on urban infrastructure including drainage, water, and sanitation - Vegetation shift in forests and biodiversity, regime shifts in rangelands, and decreased agricultural yields in tropics and sub-tropics - Increased exposure to sea-level rise *Mitigation Issues* - Increased emissions from energy production and transformation, transport, urban, agriculture, 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
Maldives	*Climate-change Impacts* - Ecosystem damages and loss of protection afforded by coral reefs - Inundation of islands due to sea-level rise and physical damages from flooding - Increased salinity of groundwater resources - Possible migration and large scale relocation
Nepal	*Climate-change Impacts* - Decline in agricultural production in some areas - Glacial lake outburst floods and future desiccation of water resources due to rapid glacial melt and impact on dependent ecosystems and agriculture - Impact of vegetation shift to forest biodiversity - Likely outbreak of malaria and similar diseases *Mitigation Issues* - Impacts on carbon sequestration of vegetation shifts and forest productivity changes - Land-use changes due to future development
Pakistan	*Climate-change Impacts* - Increased intensity and frequency of drought and effects on agriculture (pasture), water resources, and ecosystems (wetlands) - Initial flooding and future drying of water resources due to glacial melt and impact on water consumption - Damages of sea-level rise - Outbreak of heat related and insect-transmitted diseases, malnutrition, food and water insecurity, migration, and conflict *Mitigation Issues* - Increased emissions from energy, transport, and urban sectors - Emissions from agriculture and rangeland degradation

Country	Risks
Sri Lanka	*Climate-change Impacts* - Reduced crop yields due to temperature increase - Sea-level rise: damages to settlements, industries, and livelihoods in coastal areas - Saltwater intrusion in agriculture, freshwater, and groundwater - Ecosystem degradation and biodiversity loss in coastal and marine ecosystems *Mitigation Issues* - Release of stored forest carbon due to land-use changes - Increase in thermal power

PART II
Sectoral Context and Strategies



CHAPTER 5
The Sector Outlook

CHAPTER 5
The Sector Outlook[42]

There are differences among and within South Asian countries in the ability to adapt to the impacts of climate change. The capacity to adapt to climate change depends on a wide range of factors that include social, economic, and political dimensions. How these factors interact differs between and within countries and determines vulnerabilities and coping capacities. Within any sector or social group, some may be more vulnerable than others depending on their economic status and exposure to likely climate risks. Reflecting the diverse nature of the challenge, chapter 5 addresses activities in key sectors ranging from agriculture, biodiversity, energy, transport, urban development, and water to social development. It recognizes that a changing climate affects development through many lenses and an effective response must combine both mitigation and adaptation. This document advocates an integrated approach to address the impact of climate change on agriculture, ecological resources, health, infrastructure, livelihoods, and natural disasters. South Asia's heavy reliance on agriculture provides an important lesson. The impact of climate change on agriculture cannot be decoupled from water resources, floods, drought, and economic structure. These interact in ways that determine vulnerabilities, impacts and adaptation opportunities. The subsequent chapters identify the many cross-sectoral and regional linkages.

Chapter 6 on the impact of climate change on water tackles the fundamental challenge to balance more variable water supplies with accelerating water demands. The potential adverse impacts of climate change could be alleviated through enhanced cooperation and dialogue between and within regional counties. India and Bangladesh have 54 transnational rivers. Many important tributaries originate in Nepal, Bhutan, and China and supply water to Bangladesh, India, and Pakistan. Although there are agreements between some countries in the South Asia region, further regional cooperation will be required to address these future climate challenges.

Chapter 7 highlights the urgency for implementing measures that are needed to revive agricultural growth in the region and address rural poverty. With their economies closely tied to the natural resource base and climate-sensitive sectors such as agriculture, South Asian countries are expected to suffer significant losses from climate change. In this context, the impact of climate change on agriculture is an issue of great significance to the lives of millions of poor people in South Asia who depend on agriculture.

[42] Suresh Ramalingam and Richard Damania.

Chapter 8 articulates the risks from and responses to natural disasters, to which South Asia is highly vulnerable. Many of the impacts associated with climate change alter the risk profile of existing hazards, such as floods, droughts, cyclones, and other extreme weather-related events. Adaptation measures can benefit from the practical experience in disaster management. When dealing with climate-change risks, it is important to recognize the existing vulnerability to climate variability. 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. In this context, the disaster-risk-mitigation and climate-adaptation agendas require an integrated approach.

Chapter 9 provides a broad qualitative overview of the relationship between climate change and human health, which are complex and difficult to assess. In South Asia, heat waves, flooding, and increased intensity of tropical storm surges all pose threats to human well-being and health. Possibly the greatest health impacts could be those associated with population dislocation and displacement. People displaced internally or across borders are vulnerable to disease.

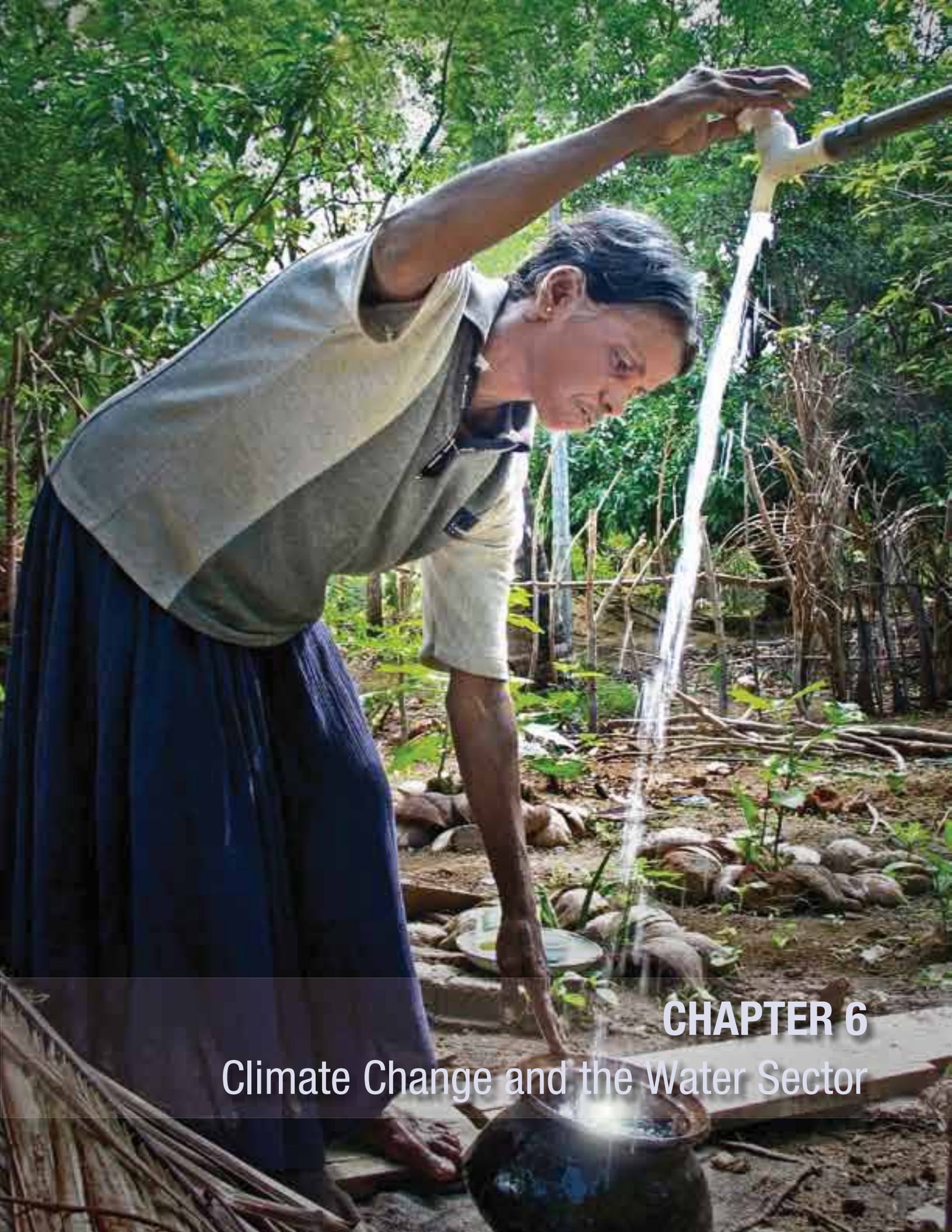
Chapter 10 highlights the social dimensions of climate change. In natural disasters, female mortality vastly exceeds that of males. Indigenous people, with their dependence on forests and natural resources, are also particularly sensitive to climate variations. The rural poor whose livelihoods are based on agriculture are another group that will be directly impacted by climate change. Chapter argues that climate change could exacerbate prevailing disparities unless the root causes of the problems are addressed. Effective adaptation strategies would need to address these fundamental disparities.

Chapter 11 looks into how climate change will increase the damage from current risks and present new challenges to the sustainability of ecosystems and their services. The region's natural resource base is currently facing tremendous pressure from rapid population and economic growth. The chapter suggests that better environmental stewardship can help build greater resilience to future climate risks and also assist with stabilizing emissions.

Chapter 12 draws attention to the opportunities for harnessing low-carbon growth in the region by addressing substantial loss of energy due to poor transmission infrastructure and inefficiencies in power generation. Rising energy demand is driven by urbanization, industrialization, and prosperity, all of which are parts of a broader process of development that is lifting millions out of poverty. However, increased energy consumption has been accompanied by rising GHG emissions. The energy that does not have to be generated due to loss reduction or efficiency gains is attractive from both the cost and the climate-change standpoints. Chapter 12 suggests that there is a need for more active and extensive interventions to tilt the balance in favor of cleaner technologies.

Chapter 13 explores the policy measures and initiatives needed to address the impending increase in transport carbon emissions. While the transport sector has been a relatively small contributor to South Asia's CO_2 emissions, the rapid pace of urbanization and likely acceleration of motorization trends present a threat to mitigation efforts in the future.

Chapter 14 investigates the vulnerability of cities to climate change and their contribution to GHG emissions. It suggests that the threats are likely to grow as cities expand in a largely unplanned manner. In general the concentration of people and assets in cities increases its vulnerability to climate change. But South Asian cities are uniquely vulnerable to climate-change impacts. This is due to a combination of nonclimatic and climatic risks. Factors such as high levels of urbanization and concentration of poor people and poor infrastructure increase the vulnerability of South Asian cities.



CHAPTER 6
Climate Change and the Water Sector

CHAPTER 6
Climate Change and the Water Sector[43]

Water Resource Supply, Demand, and Management: Why South Asia is Vulnerable

Extreme variability of rainfall is the defining feature of South Asia's climate. The monsoon is the most significant climate event: it carries more than 70 percent of the region's annual precipitation in only four months.[44] Because of the dominance of the monsoons, the region's climate exhibits the highest seasonal concentration and variability of rainfall in the world. If climate projections are indicative of future trends, the risks associated with water-related climate variability are likely to intensify and worsen.

The region is highly vulnerable to droughts and floods. Droughts vary in their intensity, duration, and spatial coverage. Climate change is likely to exacerbate damage caused by such events. Monsoonal rainfall over India has decreased by approximately 5 to 8 percent since the 1950s, which might contribute to more intense, longer, or more widespread droughts (Chung and Ramanathan 2006). It is not possible to ascribe climate change to decreased monsoonal rainfall. However, the consensus among scientists is that climate change likely impacts monsoons in ways that cannot be predicted. The region's river systems are also highly flood prone. Floods are a natural and necessary feature of river systems with variable seasonal flows. However, when floods are excessive, they cause extensive damage. Lack of well-developed infrastructure plays a significant role in curbing repeated floods. Flood-affected areas in South Asia are likely to increase as a result of climate change. In India, the area affected by floods more than doubled between 1953 (19 million hectares) and 2003 (40 million hectares) and currently represents about 11 percent of that country's geographic area (World Bank 2007a). In Bangladesh, 60 percent of the country is flood prone. In addition, farmers in northeastern Bangladesh have observed that the first flash flood has been arriving earlier in the year. The effect has become more marked in recent years, with particular impact in 2003 and 2004.[45] Since any such changes are likely to be gradual, it may not be possible to predict when and where the likely impacts of climate change could occur.

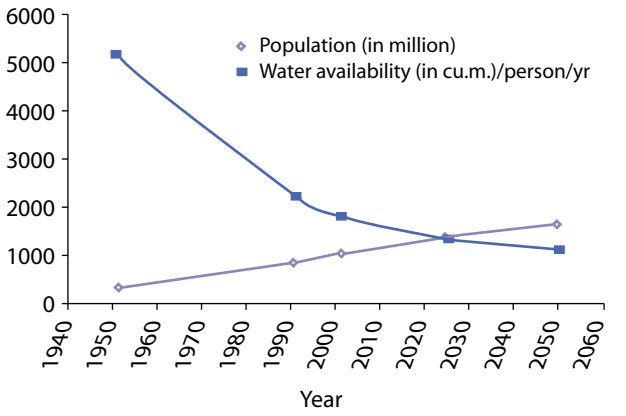
Water scarcity is another challenge. Although annual water availability appears to meet current consumption (see Figure 6.1), the data conceal

[43] Authors in alphabetical order: Ousmane Dione, Nagaraja Rao Harshadeep, and Siet Meijer.

[44] Most of the region relies on the summer monsoon, which runs from June to September. In Sri Lanka and the Maldives, however, it is the winter northeast monsoon that delivers most of the precipitation, between November and January.

[45] Bangladesh Water Development Board, http://www.bwdb.gov.bd/Flood_Flash.htm, accessed September 7, 2008).

Figure 6.1 Observed and Projected Decline in Annual Average per capita Water Availability in India



Source: Adapted from Mall et al. 2006

extreme seasonal distributional patterns. In fact, water availability has declined, and this trend is projected to continue in many places. In India, for instance, per capita water availability has steadily been decreasing as a result of decreased water availability combined with increased population. Pakistan remains the most water scarce region in the world, with growing shortages.

The region is endowed with great rivers that are the lifelines of the regional economy. These rivers include the Ganges, Brahmaputra, and Indus, all of which originate in the Himalayan Hindu Kush "water towers," fed by both rain and snowfall. The ice mass covering the Hindu Kush mountain range is the third largest in the world, after the polar

Figure 6.2 Principal Rivers of the Himalayas

Source: World Bank 2007b

Table 6.1 Major River Systems in the South Asia Region

Name of River System	Watershed Area (sq. km)	Length (km)	Average Population Density (per sq. km)	Countries within Watershed
Brahmaputra	651,335	2,900	182	4
Ganges	1,016,124	2,525	401	4
Indus	1,081,718	2,880	165	4
Godavari	319,810	1,465	202	1
Mahanadi	145,816	851	201	1
Narmada	96,271	1,312	178	1

Source: World Resources Institute 2005

icecaps. It is also the source of the nine largest rivers of Asia (Figure 6.2). These glacial masses store precipitation in the form of snow and ice, regulating water distribution and providing continuous flows during the dry months. Table 6.1 summarizes the major characteristics of the major South Asian river systems. These river basins are home to more than 700 million people, and their rivers are thus vital to the development and growth of the six South Asian countries through which they flow: Afghanistan, Bangladesh, Bhutan, India, Nepal, and Pakistan as well as China.

Likely Impacts of Climate Change

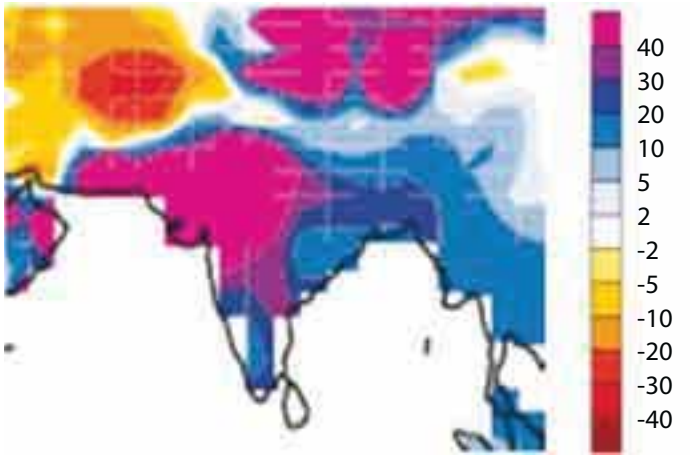
With its heavy reliance on the monsoons and snow-fed rivers, water availability in the region is highly sensitive to changes in climate. Increases in temperature are likely to result in changes in evapotranspiration, soil moisture, and infiltration. Combined with predicted changes in precipitation, this could affect water availability in soils, rivers, and lakes, which would have implications for domestic and industrial water supplies, hydropower generation, and agricultural productivity (see also Box 6.1). Several recent studies suggest that monsoons 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 et al. 2000). Climate change is likely to increase the possibility of both coastal and inland flooding, especially in Bangladesh and Sri Lanka. However, the magnitude and precise timing of these changes is unknown, as global circulation models lack accuracy at finer spatial resolutions and there remain large uncertainties in projecting local changes in climate.

The retreating of some glaciers in the Hindu Kush could pose the most far-reaching threat to the region. Due to increasing temperatures, in the past two decades the ice mass in the region has retreated at a rate of 0.3 to 1.0 meter per year, faster than the world average (Barnett, Adam, and Lettenmaier 2005). Figure 6.3 depicts this reduction in the glacial cover. The few analytical studies that exist suggest that climate change could alter the timing and rate of snow melt, with an increase in

Michael Foley/World Bank

Box 6.1 Changes in Runoff due to Climate Change

Mean Runoff Change (%): 2041–2060 vs. 1900–1970 Scenario



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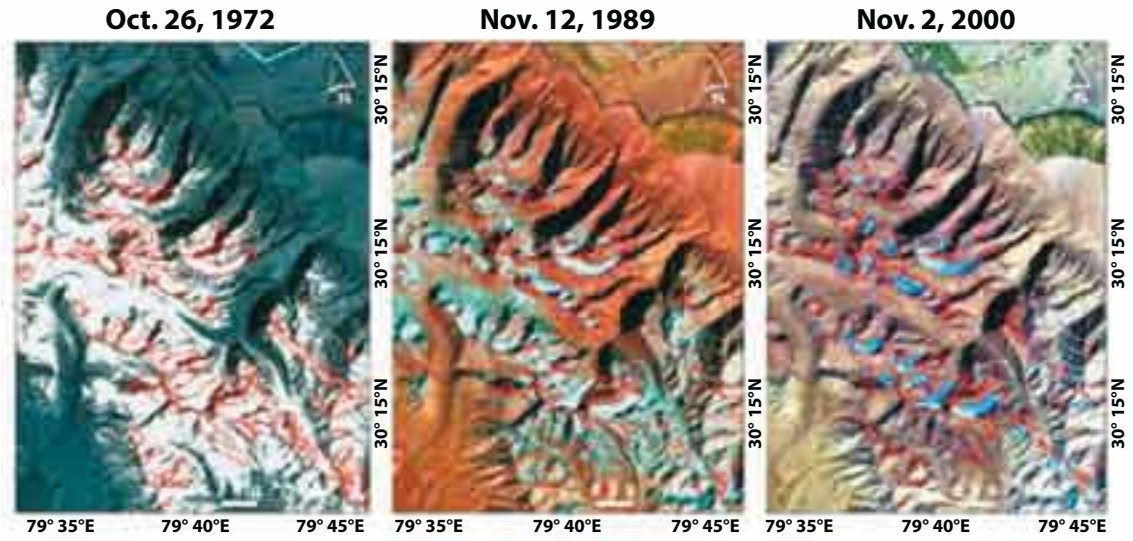
The quantity and nature of runoff is likely to change substantially in South Asia as a result of climate change. Changes in the spatial and temporal distribution of precipitation and temperature could interact in complex ways that alter the balance and characteristics of "green" water (used or lost in catchments before it reaches rivers) and "blue" water (runoff that reaches rivers). By 2050, increased runoff, primarily fed by precipitation changes and highly likely glacial melt, is expected in the basins of the Indus, Ganges, and Brahmaputra rivers. Some models show significant declines in flow in rivers such as the Indus after possible glacial melt has run its course and the evapotranspiration impacts of a likely increase in temperature begins to dominate. Afghanistan is expected to be particularly affected; flows could be reduced by almost 20 to 40 percent, posing significant implications for storage, irrigation, and the development and reliability of hydropower systems. Such outcomes will likely be complicated by changes in water use in the basins, including diversions, groundwater–surface water interactions, and increased demands for irrigation, hydropower, and domestic, industrial, and municipal water supplies from increasingly high development expectations.

annual runoff in the initial years, followed by a steep decrease in annual river flows. The uncertainty in water supplies could be exacerbated by increased incidence of extreme events, such as glacial lake outburst floods.

The precise consequences of these changes are hard to predict, but they are significant. Reduced freshwater availability during low-flow periods will become a serious problem, with considerable implications for economic activity and livelihoods.

Figure 6.3 Changes in Glacier Cover in the Western Himalayas



Source: Prasad and Singh 2007. Reproduced/modified by permission of American Geophysical Union

Agriculture (including irrigation and livestock farming) and fisheries will be negatively impacted by a reduction in freshwater availability. As a result, rural economies and livelihoods stand at significant risk. Other water-dependent sectors, such as navigation, energy production, and household water use, are also likely to be affected.

Changes in water availability will also need to be measured against the changes in demand associated with population growth. Agricultural and industrial growth will be additional determinants of future water demand. On the supply side, agriculture in South Asia has come to rely critically on groundwater, with the region now accounting for a third of the total groundwater used in the world. With the semi-arid regions in South Asia likely to expand, groundwater replenishment will be affected. Yet its role as a buffer resource will become even more important to the lives and livelihoods of people in the arid and semi-arid areas. Finally, as many of the rivers in the region are shared across national boundaries, regional coordination and cooperation will inevitably be required to allow both an increased understanding of the nature of climate challenges and the formulation of approaches to address such changes effectively.

Future Challenges and Opportunities

Looking ahead, a fundamental challenge will be the need to better balance more variable water supplies with accelerating water demands. Climate-change projections show that floods and droughts could become more common. With more rainfall expected to fall in fewer days, the region will need to tackle the increasing incidence of both droughts and floods. On the supply side, this will call for a considerable investment in infrastructure, maintenance, and water management. There will be a need to "climate-proof" high-value and long-lived water assets to withstand extreme events. A major challenge in this regard is that existing climate models lack the precision needed to guide engineering design, so there is much uncertainty about what the future climate might hold. Moreover, in a region with scarce water supplies, there is considerable wastage in both urban and rural sectors. Irrigation efficiency[46] is low throughout the region. Deteriorating water quality is another concern. Sewage and industrial effluents have turned many rivers, including major ones, into fetid waste canals. Institutional capacity to address these issues is weak throughout the region. Climate change could worsen these problems if, as a result of more frequent and more intense flooding, sedimentation, siltation, and erosion increase. In sum, large investments in both policy and infrastructure are needed to protect scarce water resources and people's livelihoods and health.

The retreating of some glaciers in the Hindu Kush add to the complexity of addressing the climate-change challenge. With melting glaciers in the near term, flood risks could increase, particularly in Bangladesh and northeast India, if peak flows from the Ganges, Brahmaputra, and Meghna coincide more frequently. In the long term, there can be no replacement for the water provided by glaciers, and their increasing retreat could result in water shortages at an unprecedented scale. Better water management techniques will help, but they alone cannot solve the problem. Agriculture and the region's economic structure are likely to undergo significant changes. Since change is a gradual process, long-term anticipatory measures are needed to minimize the human and economic impacts. This will, in turn, require considerably greater cooperation and dialogue between and among countries.

The potential impacts of climate change could be ameliorated through enhanced cooperation and dialogue between and within jurisdictions. In the past, water has been a source of discontent for countries that share transboundary rivers. India and Bangladesh have 54 transnational rivers. Many important tributaries originate in Nepal, Bhutan,

[46] See glossary.

and China and supply water to Bangladesh, India, and Pakistan. The implications of variable water supply in these shared rivers will be twofold. First, intracountry issues may arise. Examples include the often acrimonious disputes between Sindh and Punjab provinces in Pakistan over the Indus, and those between the states of Karnataka and Tamil Nadu in India over the Cauvery River. More challenging are the intercountry disputes that could be further exacerbated by the increased demand for water, which would collide with diminishing supplies. Although there currently exist agreements between some countries in the South Asia region (e.g., the Indus Treaty[47] and the Farakka Treaty[48]), further cooperation will be required to address these future climate challenges.

Managing a common problem suggests the need for a cooperative solution that would include data collection and exchange, analysis, and exploration of shared responses. Despite the fact that the challenge is of regional dimensions, water diplomacy between the countries involved has stagnated, partially due to perceptions that water allocation is a "zero-sum game," based on water rights and allocations rather than on benefit sharing. An approach to achieving progress and building joint adaptive capacity would involve shifting the debate from its current narrow focus on water rights to one that seeks to address common challenges and create positive benefits, "expanding the pie" rather than simply dividing it. In this sense, building trust and relationships through patient dialogue and the creation of a knowledge-based cooperative partnership of states will be very important. Despite the magnitude of the problem, the likely impacts of climate change on the Himalayas remain poorly understood, leading the IPCC to define the region as a data-deficient "white spot."[49] There is an urgent need for the Himalayan countries to better understand the science of climate change and its social, environmental, and economic consequences. Data sharing and scientific cooperation among countries in the region could be a realistic first step toward the creation of an institutional framework for regional cooperation.

The Future

"Climate-proofing" water resources—in other words, building more resilience to climate change—is critical to maintaining and expanding South Asia's growth. The way forward for the region requires a focus on four cross-cutting priorities:

a. **Knowledge base:** Widening the knowledge base will involve promoting national and regional initiatives that foster research, develop knowledge and data sharing among institutions, and establish a cooperative framework to advance a regional agenda aimed at increasing the exchange of knowledge and best practices. Technological components of a knowledge base approach would include greater use of geographic information systems (GIS), remote sensing and telemetry upgrading; wider application of satellite-based weather forecasting and monitoring of snow melt; and a regional early warning system for natural disasters.

b. **Policy and governance:** An adequate policy and governance structure would be required to further develop social constituencies who can advocate reforms and to help build an enabling environment in which institutions can effectively grow and cooperate on sensitive issues. While it might be premature to move toward harmonization of policies across countries, setting the basis for such harmonization might be within reach and

[47] The Indus Water Treaty (1960) the treaty between the Islamic Republic of Pakistan and the Republic of India and the Islamic Republic of Pakistan (1960).

[48] The Treaty between the Government of the Republic of India and Government of the People's Republic of Bangladesh on Sharing of the Ganga/Ganges Waters at Farakka(1996).

[49] See glossary.

could be encouraged by, for example, regional governance schemes aimed at stimulating data exchange and promoting a transboundary approach to knowledge sharing in facing the region's challenges.

c. **Investment:** Key to the overall climate-change agenda is the availability of and access to financing to address, in a timely and comprehensive fashion, the challenges associated with water resources and climate change. There is a crucial need to undertake, at an early stage, massive investment in specific areas to increase and improve the region's preparedness. The critical areas that require immediate investment are the following:

   - **Water resource management** needs to be improved through measures such as adequate training; laying out comprehensive strategies and action plans for extreme events, such as drought and floods; developing new tools, such as modeling, data collection, water allocation schemes, and financing mechanisms; strengthening institutions; and developing a transboundary conscience and regional cooperative framework that leads to actions at that level.

   - **Water infrastructure packages** that can increase water storage capacity require consideration, particularly multipurpose water infrastructure schemes associated with modernization in specific areas such as agriculture, hydropower, and transport.

   - **Water-efficient technologies** are needed that can better address the adaptation approach and include the latest technologies in water treatment, irrigation dripping, weather forecasting, and monitoring of snow melting and its related impacts.

   - **Crop research** is needed to identify and promote adaptive and water efficient crop varieties and to further the innovative use of (possibly organic) fertilizers to increase agricultural production.

   - **Education** is needed to build and enhance awareness as well as build constituencies for required behavioral changes in short- and long-term sustainable water resource management.

d. **Leveling and enhancement of skills:** There is large gap between skills available and skills required, both within countries in the region and across them. A fundamental outcome of this approach will be to address these shortcomings through training and capacity building, and through partnering with institutions across the region and abroad to promote the birth of a new multidisciplinary generation.

Table 6.2 summarizes, by country, the most important water-related climate-change issues affecting the South Asia region. It also specifies which areas require the most immediate action.

Michael Foley/World Bank

Table 6.2 Water Resources in South Asia: Climate-change issues and Priority Areas

Country	Climate-change Priorities	Scale and Magnitude	Priority Focus Areas
Afghanistan	Glacier melting in the Himalayas	Regional	Himalayan Hindu Kush
	Lake outburst	Local to national	Hill and mountain areas
	Floods and droughts	National to regional	Helmand and Kabul basins
Bangladesh	Floods	National to regional	Ganges, Brahmaputra, Meghna basins
	Increase in natural disasters	National to regional	Coastal zones
	Saltwater intrusion	Local	Coastal zones
Bhutan	Glacier melting in the Himalayas	Regional	Himalayan Hindu Kush
	Lake outburst	Local to national	Hill and mountain areas
	Floods	National to regional	Ganges tributary basins
	Droughts	Local to national	Throughout
India	Glacier melting in the Himalayas	Regional	Himalayan Hindu Kush
	Floods	National to regional	Ganges, Brahmaputra, Meghna basins
	Droughts	Local to national	Throughout
	Increase in natural disasters (cyclones)	National to regional	Coastal zones
	Saltwater intrusion	Local	Coastal zones
Maldives	Increase in natural disasters (cyclones and sea-level surges); loss of land mass	Local to national	Throughout
Nepal	Glacier melting in the Himalayas	Regional and national	Himalayan Hindu Kush
	Lake outburst	Local to national	Hill and mountain areas
	Floods	National to regional	Ganges tributary basins
	Droughts	Local to national	Throughout
	Saltwater intrusion	Local to provisional	Coastline
	Wetland desiccation and degradation	Local to national	The Ramsar Sites
Pakistan	Glacier melting in the Himalayas	Regional	Himalayan Hindu Kush
	Increased water scarcity and droughts	Local to national	Indus basin
	Saltwater intrusion	Local	Coastal zones
Sri Lanka	Increase in natural disasters (cyclones and sea-level surges)	Local to national	Coastal zones

Though the overall impacts of climate change are hard to predict, they are likely to have far-reaching consequences. Water-extreme events, such as floods and droughts, are predicted to impact more people and economies over time in South Asia than in any other region of the world. The effects of these trends will be magnified by population growth and the industrialization of South Asian economies, increasing the need to expedite progress in preparing the region to cope with the impacts of climate change. A fundamental challenge facing the water sector will be how to find a balance between increasing variability of water supply and accelerating demand for water.

CHAPTER 7
Agriculture and Rural Sector

CHAPTER 7
Agriculture and Rural Sector[50]

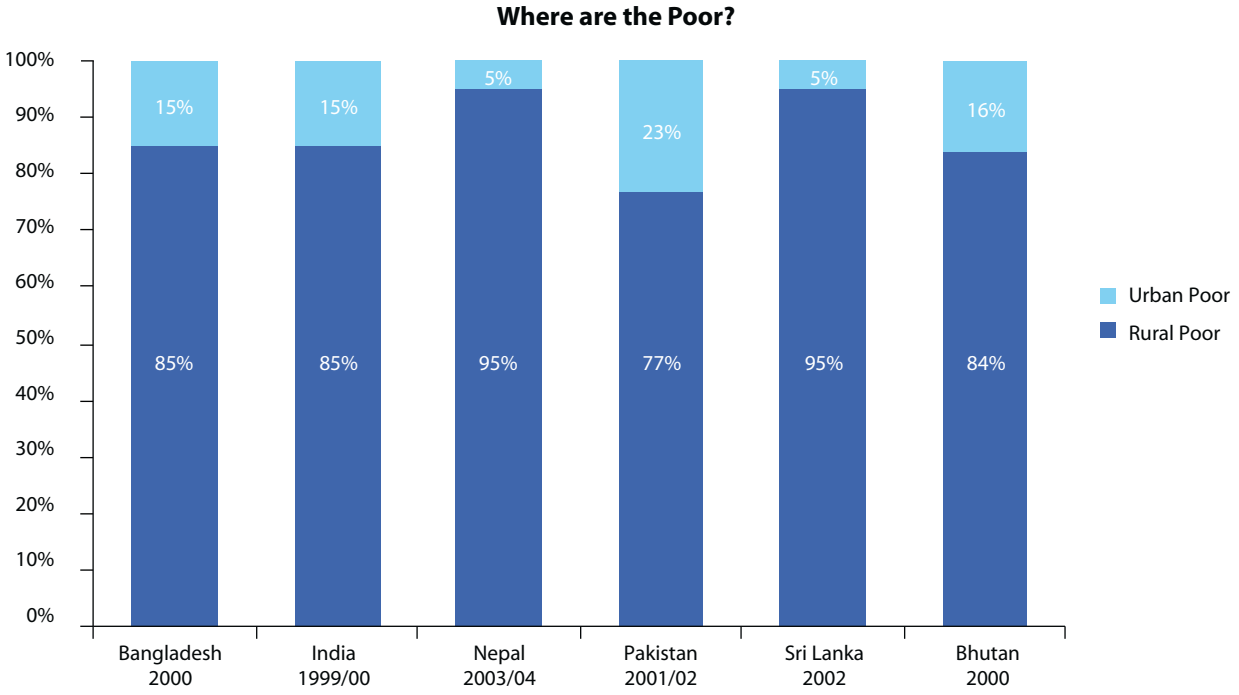
Agriculture is critical to South Asia's development. Rural areas in the region are home to more than 70 percent of its population, and agriculture is the region's principal occupation, employing more than 60 percent of the labor force. More than 75 percent of the region's poor live in rural areas (Figure 7.1) and depend on rainfed agriculture, livestock, and fragile forests for their livelihoods. Agricultural and rural nonfarm growth will be critical to reaching the Millennium Development Goal of halving the number of poor people by 2015. Meeting this challenge calls for growth that stems from agricultural productivity and raises the incomes of small-scale farmers and landless laborers. The Green Revolution of the 1970s and 1980s substantially increased food grain productivity and improved food security and rural wages. Consequently, those dramatic leaps in agricultural production raised farmer incomes, bringing a significant reduction in rural poverty. In India, for example, the rural poverty rate declined from about 53 percent in 1977/1978 to 26 percent in 1999/2000. The challenge is to replicate and sustain these achievements during the future with a more variable and unpredictable climate.

The growth of agricultural productivity has slowed down and the sector now languishes behind the other dynamic growth drivers in the region. Per capita growth in agricultural productivity in South Asia (less than 2 percent) has barely kept pace with population growth; it is also lower than that of East Asia and the Pacific (3.1 percent) and Latin America (2.8 percent). Several problems have emerged that have constrained growth: deteriorating soil fertility and declining quality of inputs such as seeds, fertilizers, and pesticides; reduced water availability; lack of access to credit; suboptimal farming practices; and lack of investment in new technologies. As a result, there is a large gap between actual yields and technologically feasible yields.

While there are many impediments to agricultural growth in South Asia, the one that threatens the economy most is the rapidly deteriorating water situation. Many parts of South Asia face growing water scarcity due to increasing water demands driven by high population growth, urbanization, agricultural needs, and industrial growth. This situation poses a particular threat to agriculture, which uses the largest share of the water consumed in South Asia. Recent work in India, for instance, demonstrates that many of the major river basins in the country will face a water deficit in the future

[50] Authors in alphabetical order: Harshadeep Nagaraja Rao, and Winston Yu.

Figure 7.1 Breakdown of Poverty (Rural/Urban) by Country



Source: World Bank calculations. Data for Afghanistan and Maldives were not available

by 2050 (Garg and Hassan 2007). This increased pressure on water availability, combined with increasing land and soil degradation, makes rational and efficient utilization of water, and related policy options that promote economic and environmental sustainability of water use, essential to long-term food security in South Asia. The problem is further compounded by the nature of small and marginal landholdings, which are characterized by highly unequal ownership of and access to productive assets such as land and water. Moreover, new challenging demands are being placed on the agricultural sector that add pressure to an already strained sector. These include compliance with sanitary and phytosanitary standards; meeting the growth needs of the biofuels industry; and addressing emerging health epidemics linked to the sector (e.g., avian flu). Addressing these challenges is important to reversing the prolonged slowdown in the agricultural sector, which is in turn essential for inclusive growth.

Climate Variability and Change

Climate change poses a particular challenge to the agricultural sector. Of all potential impacts stemming from climate change, those to the agricultural sector stand out as among the most important. Long-term changes in temperatures and precipitation have direct implications on evaporative demands and agricultural yields. It is true that, in some areas, some reduction in yields may be offset by carbon fertilization and increased precipitation (Box 7.1). However, this opportunity is likely to be limited in scope and only applicable to certain species. A large portion of the population in the region is already vulnerable to a range of natural hazards and extreme weather events (e.g., floods or droughts). The changing hydrological characteristics of these extreme events, in relation to the onset, duration, and magnitude of the yearly monsoon season, will affect agricultural production significantly. The combined effects could be

Box 7.1 Carbon Fertilization Effects

The extent to which increased carbon dioxide levels in the atmosphere may actually improve crop yields ("carbon fertilization") is a subject of current interest. Much of the debate is focused on the different ways plants fix carbon dioxide. C3 crops, which include rice, wheat, soybeans, fine grains, legumes, and most trees, benefit substantially from increased carbon dioxide levels; C4 crops, which include maize, millet, sorghum, and sugarcane, benefit much less.

Recent research based on experiments using the free air concentration enrichment method, which involves pumping carbon dioxide into the open air surrounding crops grown in fields (to simulate more realistic conditions than previous closed-condition studies), suggests that past estimates of the carbon fertilization effect may have been substantially overstated (Long et al. 2005). Elevation of carbon dioxide levels to 550 to 575 parts per million (ppm) resulted in a yield increase of 11 percent for C3 crops and 7 percent for the world's five major grain crops: maize, rice, sorghum, soybean, and wheat. This was about one-third to one-quarter of the effect modeled in a 2000 assessment for Europe and the United States by Darwin and Kennedy (2000).

devastating for tropical agriculture. In Bangladesh alone, between 1991 and 2000, 93 major natural disasters were recorded, with the agricultural sector suffering the bulk of the losses.[51] Finally, sea-level rise could have important implications for the availability of land for agriculture. Inundation and changes in the sediment balance and salinity profile of coastal areas could affect large areas of fertile arable land across much of the region.

Climate change may stress rural livelihoods beyond agriculture alone. Climate-induced changes to resource flows (e.g., natural resources, water, biomass) can fundamentally affect the viability of the livelihoods of the rural poor. Resilience is typically low in rural areas as the existing asset base is weak (natural, human, physical, financial, social) and services provided by infrastructure and institutions are often insufficient. Thus, the rural poor are chronically vulnerable to climatic conditions beyond direct agriculture production impacts. This is especially true during natural disasters and in existing climate sensitive areas (e.g., drought-prone and flood-affected areas) where the ability to cope with current climate variability is low. The prospect of increasing climate risks underscores the importance of a more integrated and holistic approach to development in the rural areas. For instance, in addition to traditional agriculture activities, including livestock and fisheries, supporting socioeconomic activities beyond agriculture are needed to promote livelihood diversification.

Costs of Climate Change in the Agricultural Sector

Measuring the precise economic impacts of climate change on agriculture is difficult because of uncertainty. First, the exact magnitude of impacts is uncertain because the complex biophysical interactions and feedback processes are poorly understood. Second, any assessment of climate impacts on the agricultural sector must be

Michael Foley/World Bank

[51] Emergency Events Database (EM-DAT: The OFDA/CRED International Disaster Database), http://www.em-dat.net.

Box 7.2 Food Price Crisis

The surge in global commodity prices of the past few years has presented a tremendous development challenge to South Asian countries. On a net basis South Asia is estimated to have suffered an income loss equivalent to some 9.6 percent of GDP between January 2003 and April 2008. Although much of the income loss resulted from the hike in petroleum prices, the surge in food prices between January 2007 and April 2008, especially of staple food—wheat and rice—has created a tremendous adverse social impact in South Asia. All countries have witnessed unprecedented surges in food prices, although India was largely able to limit this increase through a combination of timely interventions. Net food importing countries like Afghanistan, Sri Lanka, and Bangladesh have suffered the most from the food price crisis. The adverse effect of the rise in global commodity prices on macroeconomic balances has been substantial. South Asian countries have seen a sharp increase in fiscal deficits and a worsening in the balance of payments. Inflation has been hit badly. For the first time in decades countries have simultaneously experienced double digit inflation rates, exceeding 20 percent in Afghanistan, Pakistan, and Sri Lanka. Economic growth is showing signs of slowdown. The emerging global financial crisis is adding fuel to the fire, with further adverse consequences for macroeconomic balances and growth.

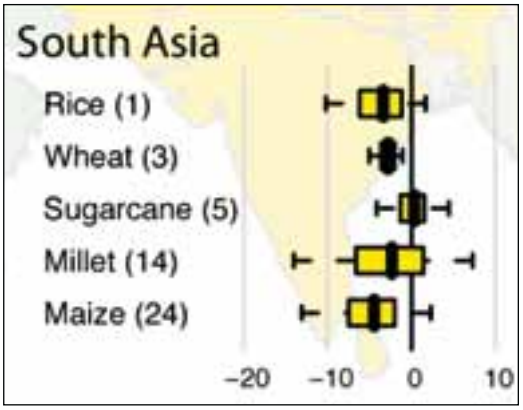
Source: Ahmed 2008.

undertaken against the background of a volatile global food supply and demand system (see Box 7.2 on food price crisis, for example) that is affected by changing socioeconomic conditions, such as population growth, increasing urbanization, changing patterns in consumption and trade, and technology development. These future socioeconomic uncertainties may in fact dominant most impact assessments.

Several approaches to assessing the impacts of climate change on crops are typical. Three common methods are (i) statistical assessments (termed neo-Ricardian models) that examine actual farmers' responses to climate variation; (ii) agronomic crop models that simulate plant growth and biophysical changes to the climate; and (iii) hybrid approaches that combine both elements (Cline 2007) (see Box 7.3).

Box 7.3 Approaches to Measuring Climate Impacts on Yields

The Ricardian approach makes use of cross-sectional data to capture the influence of climatic as well as economic and other factors on land values (or farm income). This technique implicitly captures the adaptation measures that farmers will adopt as the climate changes. Moreover, it is assumed that because farmer adaptations will be reflected in land values, the costs and benefits of adaptation are embedded in those values. This approach is used to generate estimates of farm performance across different climate conditions that can be used to infer the consequences of future climate change.



Alternatively, a crop model (or agronomic) approach can be used whereby models are calibrated from controlled field experiments that are designed to simulate climate events and different management regimes. Typically, these models assume that farmers do not respond to predictably changing conditions, nor do they learn from past experiences. As a result, estimates of the costs of adapting to climate change are often larger than those derived from Ricardian approaches.

The accompanying figure shows the 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 one hundred 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, calculated by factoring in the number of malnourished people in the region and the percentage of calories they derive from the crop.

Table 7.1 Estimates of Climate-change-related Impacts on Agricultural Production by 2080 for Selected Countries in the South Asia Region

Country[a]	Farm Area (1,000 ha)	Output per Hectare (US$)[a]	Output (US$mil)b	% Change (Ricardian)	% Change (crop models)
Afghanistan	7,827	313	2,448	–9.5	–32.1
Bangladesh	8,429	1,355	11,421	–14.3	–25.3
India	170,115	777	132,140	–49.2	–27.0
Nepal	3,294	728	2,399	–0.9	–25.3
Pakistan	22,120	856	18,935	–17.9	–36.6
Sri Lanka	1,916	1,808	3,465	–9.5	–25.3

Source: Cline 2007

Note: Estimates are based on the A2 scenario of the Special Report on Emission Scenarios (SRES) (Nakicenovic and Swart 2000) and a rough average increase in temperature of 3.3°C.

a. Bhutan and Maldives are too small to be resolved with climate data at a 0.5 x 0.5 degree resolution.

b. At 2003 price levels.

There is a strong consensus that climate change is likely to have severe consequences on the agricultural sector and the rural poor in South Asia. Using a range of different approaches, Cline (2007) estimated broad impacts for a number of South Asian countries. The estimates vary substantially, from as little as a 1 percent loss of agricultural revenues in Nepal to a dramatic 49 percent decline in average revenue in India by 2080 (Table 7.1).

These estimated changes do not consider crop losses arising from more intense droughts and floods; changes in surface water availability; or threshold effects in the response of crop growth to temperature changes. Nor do they take into account that, for agriculture that is being practiced in low-lying coastal areas (e.g., Bangladesh, and the Mahanadi delta in India), there is also potential for damage arising from sea-level rise and increased saltwater intrusion in groundwater aquifers.

More precise estimates are available for select countries in South Asia and are described in the following subsections.

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India

Reflecting India's immense geographic diversity, the projected impacts of climate change on crop yields vary by region. In arid locations where crops already suffer heat stress, a small increase in temperatures could lead to a dramatic decline in yields. The same temperature increase in, say, the cooler Himalayas could generate an increase in yields. Accordingly, agronomic models project a wide range of impacts that vary by location and climate scenario.[52] Table 7.2 and Table 7.3 summarize

[52] For instance, the yield impacts for rice vary from increases of 22 percent in western India to a reduction of 20 percent in the country's drier central belt.

Table 7.2 Results of Ricardian Assessments for Selected Crops in India

Temperature Change	% Change (net agricultural revenue per hectare)	Source
2°C	–3 to –6	Sanghi, Mendelsohn, and Dinar 1998
2°C	–7 to –9	Kumar and Parikh 1998
2°C	–8	Kumar and Parikh 2001
3.5°C	–20 to –26	Kumar and Parikh 1998
3.5°C	–3 to –8	Sanghi, Mendelsohn, and Dinar 1998

the results from studies that have measured the resulting economic losses using the statistical (Ricardian) approach and the agronomic crop model approach(es), respectively. The Ricardian models suggest that a temperature increase of 2°C would generate a modest loss of between 3 and 9 percent of current agricultural income (net revenue per hectare). However, for a 3°C rise in temperature, the studies predict a wide range of losses from 3 to 26 percent of income. The estimates are broad and approximate averages need to be treated with caution. In the case of studies that utilize agronomic models, the results also show considerable variation. A general trend that can be ascertained is that increases in temperature greater than 2°C cause higher reductions in yields, which are further exacerbated if rainfall is not increased or is reduced.

Table 7.3 Results of Agronomic Assessments for Crops in India

Crop	Yield Change (%)	Scenario	Model
Lal et al. 1998: northwest India			
Rice	0	+2°C; doubling CO2	CERES-Rice
	–20	+2°C; doubling CO2; water shortage	
Wheat	0	+3°C; doubling CO2	CERES-Wheat
Lal et al. 1999: Madhya Pradesh			
Soybean	From –4 to 0	+3°C; doubling CO2; –10% daily rainfall	CROPGRO
Saseendran et al. 2000: Kerala			
Rice	–6	+1.5°C	CERES-Rice
	+12	+1.5°C; +2 mm/day rainfall; 460 ppm CO2	
Aggarwal and Mall 2002: parts of northern, eastern, southern, and western India[a]			
Rice	From +3.5 to +4.3 (2010) From +13.8 to +22.3 (2070)	Optimistic IPCC scenarios: +0.1°C, 416 ppm CO2; +0.4°C, 755 ppm CO2. Both at current crop management level[b]	CERES-Rice
	From +1.3 to +1.9 (2010) From +3.6 to +9 (2070)	Pessimistic IPCC scenarios: +0.3°C, 397 ppm CO2; +2°C, 605 ppm CO2. Both at current crop management level	
	From +5.1 to +7.4 (2010) From +16.6 to +25.7 (2070)	Optimistic IPCC scenarios	ORYZAIN
	From +2.5 to +4.1 (2010) From +6.1 to +16.8 (2070)	Pessimistic IPCC scenarios	
Kalra et al. 2007: DEFRA study			
Rice	–5 to –8	+1°C; no change in CO2	CERES-Rice
	–10 to –16	+2°C; no change in CO2	
	–21 to –30	+4°C	

Crop	Yield Change (%)	Scenario	Model
Maize	–10 to –30	+1°C to +4°C; 350 ppm CO2	CERES-Maize
Jowar	–7	+1°C	CERES-Sorghum
	–12	+2°C[c]	
World Bank 2006a			
Rice	–9	Max. temp. +2°C; min. temp. +4°C; annual rainy days –5%; 550 ppm CO2	EPIC
Groundnut	+2		
Jowar	+3		
Sunflower	+10		
Maize	+3		
Rice	–8	Max. temp. +2°C; min. temp. +4°C; annual rainy days –5%; 550 ppm CO2; cumulative monsoon rainfall (Jun–Sept) –10%	
Groundnut	0		
Jowar	0		
Sunflower	+9		
Maize	0		

a. Margin of error can be as much as 32 percent, depending on the uncertainty in climate-change scenario and other factors. Sensitivity analyses were run for increases in temperature, level of nutrients fed to the crops, and variations in CO2 levels. These showed that, as long as temperature remains unchanged and CO2 levels increase, yields will increase. However, with temperature increases, this CO2 effect is nullified for increases in temperature as low as 0.9°C.

b. "Current crop management level" assumes no change in current nutrient application and irrigation.

c. Further increases in temperature resulted always in lower yields irrespective of increases in CO2. The beneficial effect of additional CO2 up to 700 ppm was nullified by an increase of only 0.9°C.

Bangladesh

Bangladesh is especially vulnerable to climate change and natural disasters. Cyclones, storm surges, floods, and coastal erosion are frequent occurrences in Bangladesh. It is ranked as one of the most natural-disaster-prone countries on the planet, due to the frequency of extreme climate events and its high population density (World Bank 2005). In most years between 20 to 30 percent of the country's area is affected by floods. The huge sediment loads carried by three Himalayan rivers, coupled with drainage congestion problems, exacerbate the extent of flooding. Climate change is projected to increase the intensity and frequency of natural disasters and to cause changes in agricultural yields, with potentially severe implications for rural poverty. The majority of assessments predict a decline in rice yields. For instance, Karim et al. (1999) anticipate a 17 percent decline in overall rice production and a decline as high as 60 percent in wheat production, compared to the baseline situation (1994/1995). Wheat and *aus* varieties of rice showed the highest yield impacts. Crop-modeling results also suggest that the duration of the growing season could decrease by 2 to 12 days, which may delay the *aman* transplantation (which occurs in December and January). Moisture stress during lean times may also further contribute to a reduction in the yields of *boro* rice (March to May).

Floods (more intense or longer than normal) can also significantly affect agricultural production. The 1998 flood, for example, caused a 45 percent reduction in agricultural production that year. Moreover, the *aman* production potential of about 2 to 2.3 million hectares could not be realized due to those floods, which lasted 67 days (FAO 1998). As seedlings could not be planted in the flood-affected areas, the resulting estimated shortfall of food-grain production exceeded 3.5 million metric tons. Higher discharge and low drainage capacity, in combination with increased backwater effects, would increase the frequency of such devastating

floods. Calculation of the economic costs of recent extraordinary flood events (1998 and 2004) have shown that much of the total economic losses are attributable to the agricultural sector (almost US$700 million in 2004 and affecting almost 5 million families or 42 percent of all farm families) (Karim et al. 1999). Sea-level rise would also impact agriculture, but the consequences are poorly understood. Tentative estimates indicate that the loss of food-grain production due to soil salinity intrusion from sea-level rise in the coastal districts could be as much as 40 percent.

Sri Lanka

There is much uncertainty about the likely impacts of climate change in Sri Lanka and assessments are sparse. A recent study by Ajwad et al. (2004) uses the statistical (Ricardian) approach to estimate the impacts of climate change on the smallholder agricultural sector in the country. The effect of predicted climate change depends on the scenario used. With mild warming and a large increase in precipitation, net revenue per hectare is projected to increase by 22 percent. On the other hand, with medium warming and only a small increase in precipitation, losses of 23 percent are projected. These impacts are, however, highly location-specific (Figure 7.2). The wet, high-elevation areas are expected to benefit from climate change, while the hot, dry northwestern and southeastern lowlands will be adversely affected. Changes in precipitation are expected to have more impact than temperature changes, especially during key agricultural production months.

Adaptation in the Agricultural Sector

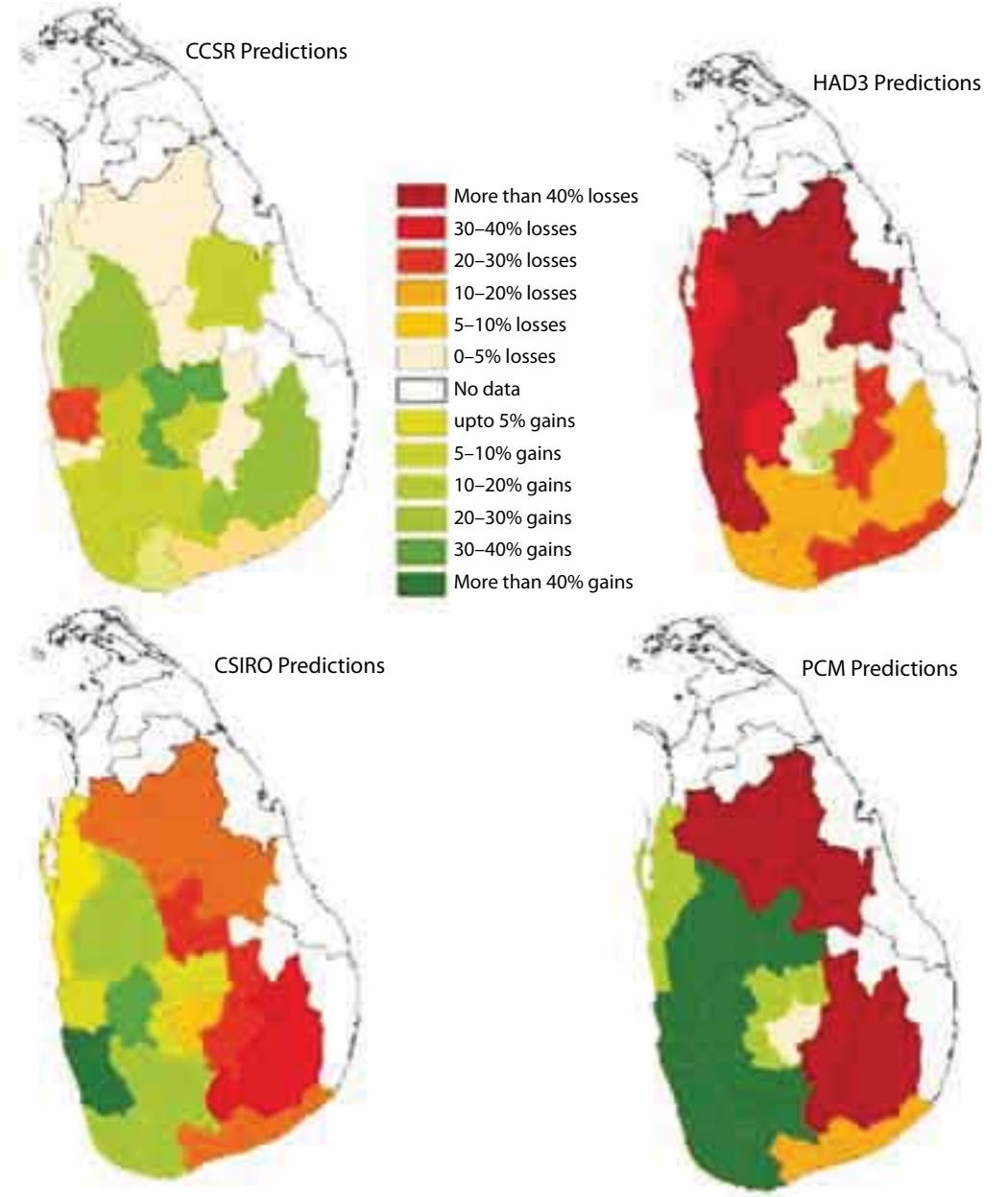
It is in the context of these potential economic consequences that adaptation measures are needed urgently to reduce the likely adverse impacts stemming from climate change. Many communities in the South Asia region already face extreme climate variability, both annually (floods and droughts) and in the longer term (El Niño events, long-term shifts in mean climate parameters). Current agricultural systems are often poorly equipped to deal with climate variability. If agricultural communities can be made more resilient to current climate risks, they will be better prepared to face future climate risks.

Many different adaptation practices are possible. In some cases, farmers are already adapting by planting resilient crop varieties, changing planting dates, and adapting farming practices to a shorter growing season. In other cases, however, there exist large barriers to adaptation, often related to policy shortcomings and resource constraints. Examples include price controls that promote water-intensive cropping in arid areas; input (e.g., power supply) subsidies that encourage over-abstraction of groundwater; poor irrigation practices; lack of credit or savings; weak extension services; lack of access to improved seeds and inputs; and inadequate agricultural research and technology. Thus, the public sector can facilitate adaptation through improved policy measures such as crop and livestock insurance, social safety nets, research on and dissemination of flood, heat, and drought-resistance crops, including conservation of traditional plant varieties with those characteristics, and in some instances support to new irrigation schemes.

Climate change increases the urgency for implementing measures that are needed to ignite agricultural growth in the region and address rural poverty. In this respect, the region's priorities lie in four core areas:

a. **Research on and dissemination of climate-resilient agriculture:** New climate-resilient agricultural technologies are increasingly complex, knowledge intensive, and location specific. They require considerable investment in research and sophisticated systems of extension and dissemination. The Bank and its partners can play a key role in encouraging

Figure 7.2 Sri Lanka: Distribution of Climate Impacts on Smallholder Agricultural Net Revenues per Hectare Based on Alternative Climate Scenarios



* Based on aggregaing impacts at the household level North and Eastern Provinces excluded

Source: Ajwad et al. 2004 (reproduced with permission)

research and facilitating the adoption of climate-resilient technologies (e.g., drought-, pest-, and saline-resistant crop varieties). Biotechnology will also have an important role to play in developing new, more resilient varieties of crops.

b. **Provision of better climate information through improved forecasting and early warning systems.** With possible changes in the timing and magnitude of monsoon events, building human and technical capacity and community systems to better

prepare for and respond to the wide range of climate risks (e.g. floods, cyclones, droughts) will be critical to sustaining agricultural growth rates in the region and improving rural livelihoods. Although many different information channels exist for farmers, few of them are sufficiently customized that they are able to improve farmers' productivity and incomes. This will require the strengthening of existing agricultural extension services and other community dissemination means (e.g., information kiosks, community agroclimatic atlases) to provide farmers with improved access to real-time climate information. Improving information dissemination can also help to remove existing barriers to adaptation.

c. **Improved water-resource management (further details described in chapter 4):** Adequate water provision presents the most serious challenge to agriculture. Water is becoming increasingly scarce as rising demand from agriculture and industry encounters the diminishing potential for the expansion of water supply. Climate change is projected to increase water scarcity through much of the region. In this context, policies that improve water management and encourage prudent water use will help build more climate-resilient agricultural systems. In addition, irrigation systems in the region are often poorly maintained and rapidly deteriorating, thus accelerating water losses. A priority of the Bank could be to improve irrigation systems, create water storage systems, and increase access to water in dryland farming areas and areas vulnerable to recurrent droughts. In flood-prone areas, the priority is to facilitate improvements to drainage systems and flood protection works. Lastly, at the community level, introducing methods to conserve soil and water (e.g., lining canals, dry seeding of rice, furrow irrigation, zero tillage) will help to improve the productivity of increasingly scarce land and water resources.

d. **Improvements in risk management:** Due to the high degree of uncertainty about the future climate, new innovative financial mechanisms are required to protect the agricultural assets upon which so many depend. Strengthening current agricultural and weather insurance mechanisms will be critical. Along similar lines, mapping vulnerable areas and developing and implementing region-specific contingency plans, based on vulnerability and risk assessments, will help to better prepare communities for the challenges that lie ahead. With the advent of extreme climate events, having proper safety nets in place will be important for the protection of those who are most vulnerable.

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Many of these measures may be effective at reducing climate risks, especially when combined with complementary reforms and better market access for high-value products. Finally, mainstreaming climate-change and climate-risk issues into the broader economic agenda, rather than taking a narrow agricultural view, will also be critical.

Adaptation and Mitigation Links

Agriculture is also a major source of greenhouse gas emissions. Crops and livestock are large contributors to GHG emissions, primarily of methane and nitrous oxide. In India, for instance, of a total of 1,469 teragrams (Tg) of CO_2-equivalent greenhouse gases emitted in 2000, almost 13 percent came from livestock-related activities (including both CH_4 and N_2O contributions; these two gases represented 30 percent of total greenhouse gas emissions)[53] (Table 7.4). CH_4 emissions dominate in comparison to those of N_2O. With almost 300 million cattle and buffalo in the country,[54] livestock contributions to Indian emissions are significant; the negative balance of such emissions is also considerable, due to the generally low productivity and efficiency of livestock farming in the country (and throughout much of the region).

Agriculture has much untapped potential to reduce such emissions through changes in land use and agricultural practices, and by reducing deforestation. The most promising area for reduction in methane emissions is in the livestock sector. Improving the diet of livestock can both improve their overall productivity (methane production currently results in a 5 to 15 percent loss of energy) and reduce methane emissions. Swamy and Bhattacharya (2006) find that feed conversion efficiency can be improved through (i) replacement of roughages with concentrates and a change in composition of concentrations; (ii) modification in feeding (e.g., alkali/ammonia treatment of low digestibility straws); and (iii) supplementation with molasses or urea nutrient blocks. If livestock manure is kept under aerobic conditions by turning regularly, methane emissions can also be reduced by as much as 30 to 40 percent.

Emissions of carbon dioxide can be further reduced by slowing deforestation; through changes in agricultural land management such as conservation tillage, agroforestry, and rehabilitation of degraded crop and pasture land; utilizing storage and capture technologies for manure; and conversion of emissions into biogas. Opportunities through carbon trading are in principle quite large and offer new possibilities for agriculture to benefit from land uses that sequester carbon.

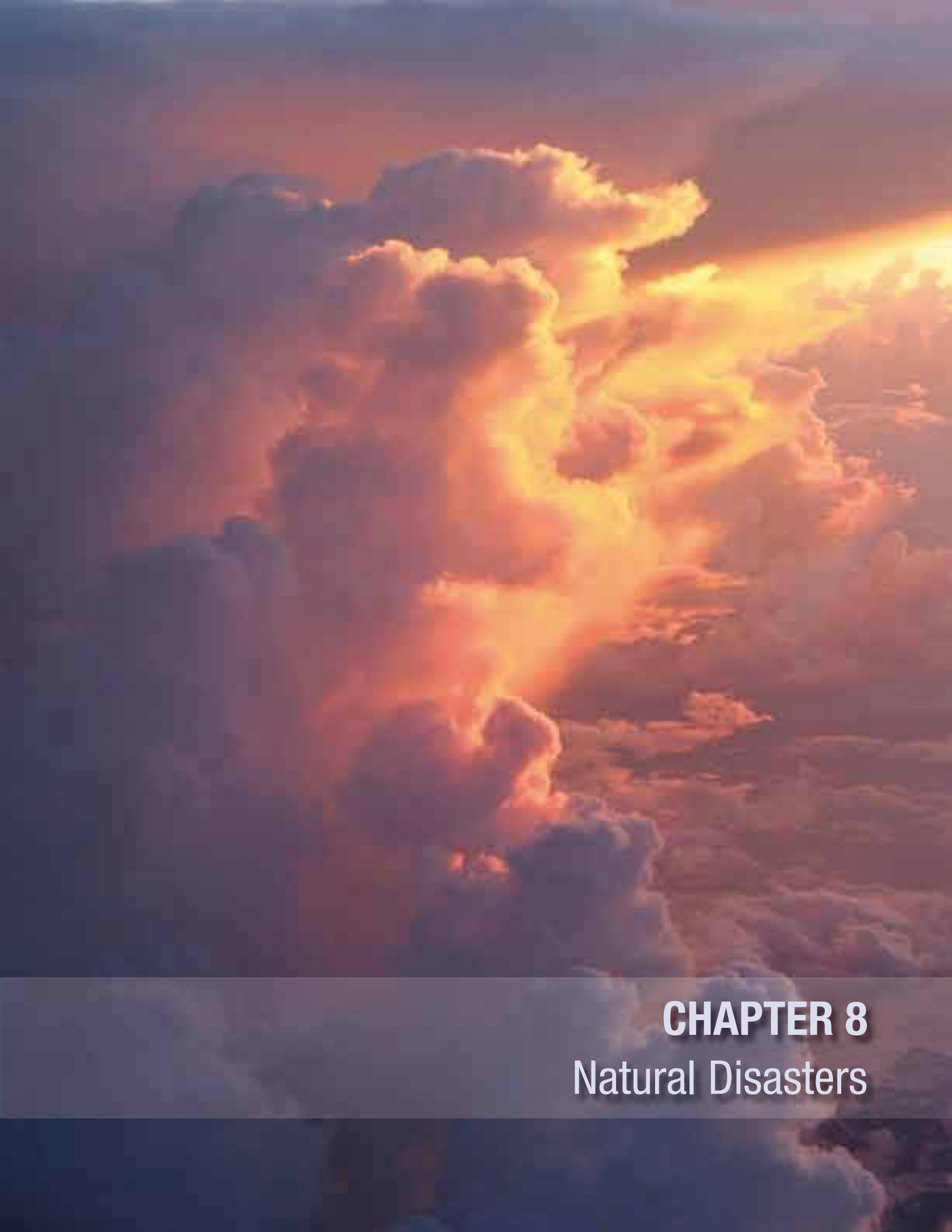
Table 7.4 Contributors to Indian CO_2-equivalent Greenhouse Gas Emissions in 2000

Source categories	Main Emissions	% Share
Coal-based electricity	CO2	29.9
Steel industry	CO2	8.8
Cement industry	CO2	5.1
Livestock related	CH4, N2O	12.6
Paddy cultivation	CH4	6.6
Biomass consumption	CH4, N2O	5.2
Synthetic fertilizer use	N2O	4.1
Transport sector	CO2	9.5
Waste disposal	CH4	3.8
Other sources	CO2, CH4, N2O	14.4

Source: Garg and Shukla 2002

[53] In 2000, methane emissions were 18.6 Tg; NO_2 emissions were 0.308 Tg. Amounts are converted into equivalent CO_2 by multiplying by the global warming potentials of 21 and 310, respectively. That is, methane and NO_2 have a greater potential to warm compared to an equivalent mass of CO_2. Other contributors to methane and NO_2 emissions include rice paddy cultivation, municipal solid waste, and biomass burning.

[54] Based on livestock census data (1997).



CHAPTER 8
Natural Disasters

CHAPTER 8
Natural Disasters[55]

Toll of Natural Disasters

South Asia is extremely vulnerable to natural disasters, with more than 900 events reported since 1970 alone. Between 1990 and 2008, more than 750 million people—50 percent of the population in the region—were affected by at least one natural disaster, leaving almost 230,000 deaths and about US$45 billion in damages (Table 8.1).

The toll of natural disasters is high and rising. Since 1970, the number of reported natural disasters in the region has been rising steadily (Figure 8.1). Figure 8.2 shows the principal hazard risks in the region and the distribution of the "hotspots" where they are most likely to be encountered. These hotspots occupy a significant portion of the geographic territory, with several parts being susceptible to more than one type of

Table 8.1 Reported Natural Disaster Impacts in South Asia (1990–2008)

Country	Population[56] ('000)	Deaths ('000)	People Affected ('000)	Population Affected (%)[57]	Damage (US$millions)
Afghanistan	22,615	6.1	5,410	23.9	69,060
Bangladesh	143,990	155.3	145,713	101.2	12,984,000
Bhutan	602	0.2	66	11.0	3,500
India	1,071,608	53.4	885,244	82.6	25,743,100
Maldives	279	0.0	2	0.7	500,100
Nepal	25,278	4.6	2,796	11.1	245,100
Pakistan	162,662	9.4	27,943	17.2	3,573,054
Sri Lanka	19,258	0.5	6,331	32.9	1,670,070
Total	**1,368,327**	**229.5**	**1,073,504**	**78.5**	**44,787,984**

Source: Emergency Events Database (EM-DAT: The OFDA/CRED International Disaster Database) (http://www.em-dat.net) and United Nations World Population Prospects (http://esa.un.org)

[55] Authors in alphabetical order: Siet Meijer, Christophe Pusch, and Ranu Sinha.

[56] United Nations World Population Prospects, http://esa.un.org.

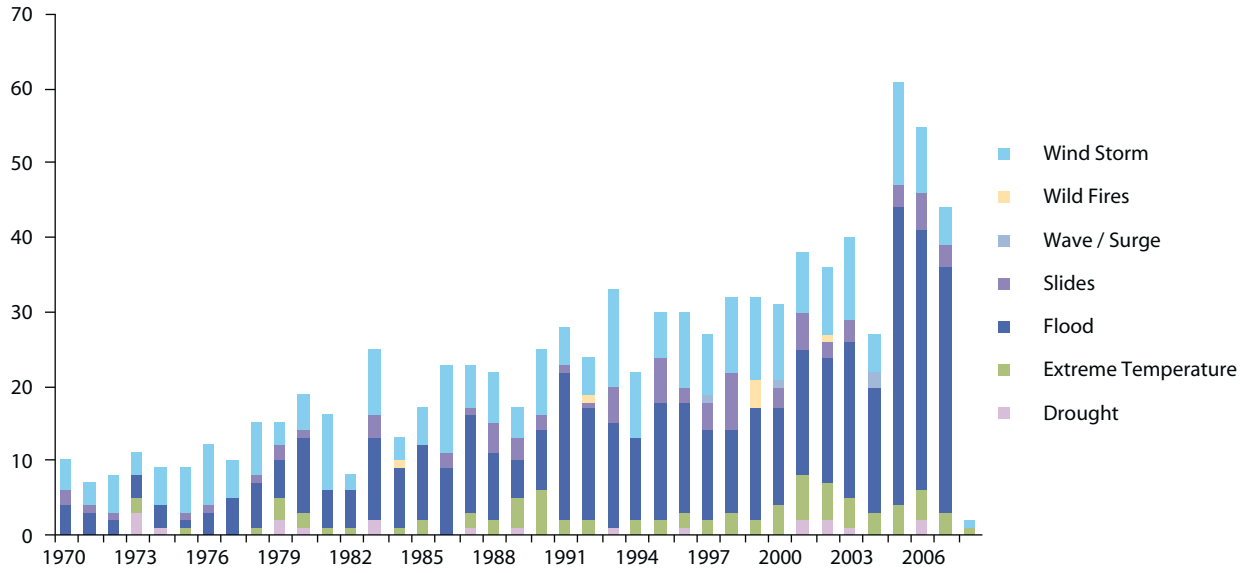
[57] Because this is the total number of people affected over 18 years, percentage affected as a proportion of average population over this time can be higher than 100 percent, since it indicates multiple exposures to disasters.

climate-related hazard. With a coastline of 12,000 kilometers as well as low-lying lands and many islands, the region is highly vulnerable to cyclones, storm surges, and sea-level rise. As shown in Figure 8.2, significant portions of Bangladesh, India, Nepal, and Sri Lanka are prone to flooding. In the 1970–2008 period, floods accounted for 50 percent of the total number of events reported, while droughts accounted for 2 percent (Figure 8.1). Nevertheless, droughts affected more than 50 percent of the total number of affected people.[58] Droughts normally occur as a consequence of rainfall deficiency and low air humidity. The arid and semi-arid regions of Afghanistan, India, and Pakistan experience significant drought. Though droughts seldom result in structural damage, they generally extend over a larger geographic area than damages from other natural hazards (American Meteorological Society 2003).

Global warming has been correlated with an upward trend in the destructive potential of hurricanes (Emanuel 2005). The eastern coast cyclones originate in the Bay of Bengal, the Andaman Sea, and the South China Sea and move toward the coasts of West Bengal, Orissa, and Andhra Pradesh, eastern and north central parts of Sri Lanka, and the coastal areas of Bangladesh. Recently, observed trends in the intensity of tropical cyclones—Cyclone Yemyin, for example, affected 2.5 million people in the southern provinces of Pakistan alone.—There is a possibility that the region may face an even stormier future This prospect might be partially shaped by an increase in sea-surface temperature resulting from climate change.

The areas and populations that face the highest risk from natural disasters are located in Bangladesh and Nepal (Table 8.2). However, with 436 events since the 1950s and almost 2 billion people (cumulative) affected during this period, it is India that has suffered the most extensive damage. Population growth and increased infrastructure density in disaster-prone areas only exacerbate this risk.

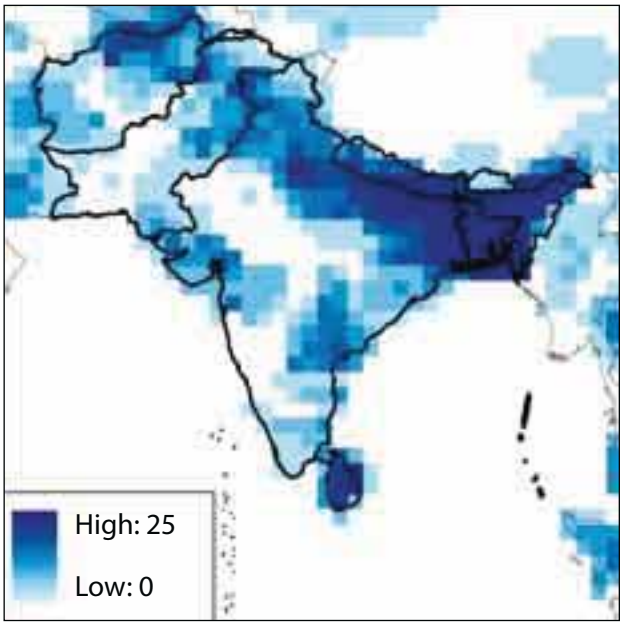
Figure 8.1 Numbers of Reported Disasters in South Asia by Disaster Type (1970–2008)



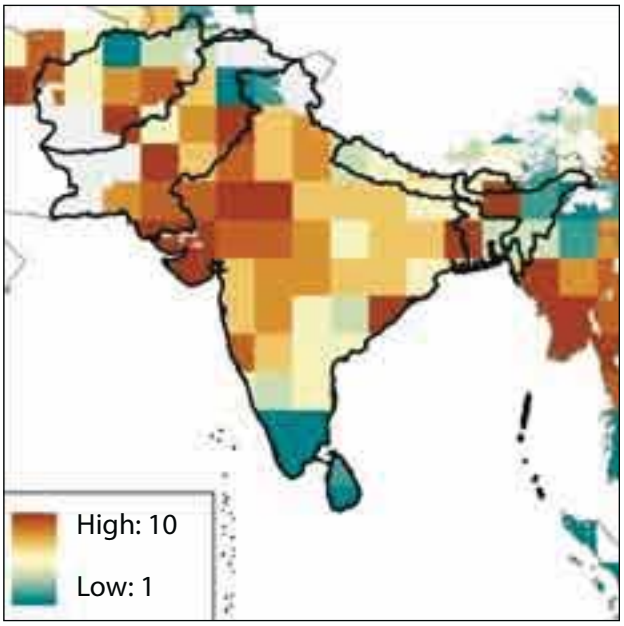
Source: Emergency Events Database (EM-DAT: The OFDA/CRED International Disaster Database) (http//www.em-dat.net).

[58] Emergency Events Database (EM-DAT: The OFDA/CRED International Disaster Database) (http://www.em-dat.net).

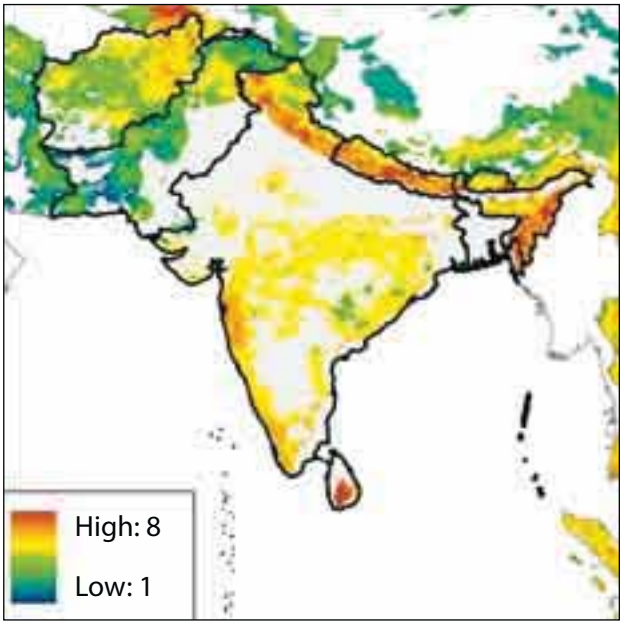
Figure 8.2 Distribution of Hazard Risk Hotspots in South Asia



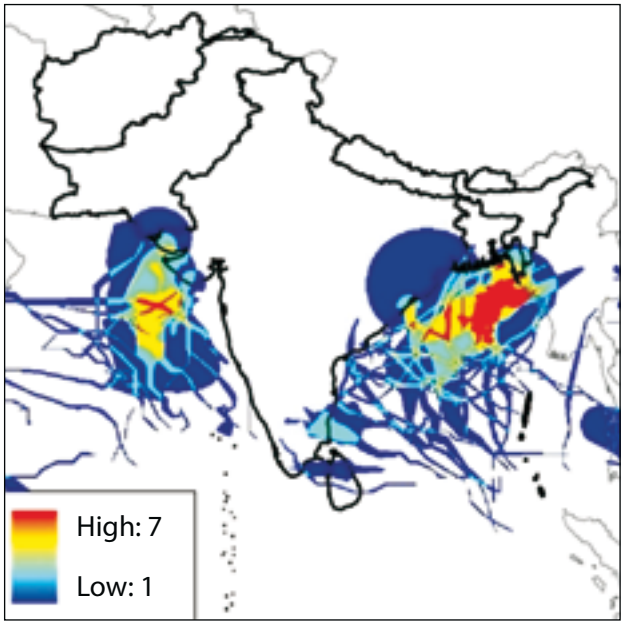
Map 1: Flood frequency index[59]



Map 2: Drought frequency index[60]



Map 3: Slides frequency index[61]



Map 4: Cyclone frequency index[62]

Source: Reproduced/modified from Dilley et al. 2005

[59] Maps 1–4 display the South Asia region with hazards data that are derived from a global source, reproduced/modified from Dilley et al. 2005.

[60] Ibid.

[61] Ibid.

[62] Ibid.

Table 8.2 Countries at Relatively High Mortality Risk from Multiple Hazards[a]

Global Rank	Country	Total Area at Risk (%)	Population in Risk Areas (%)
1	Bangladesh	97.1	97.7
2	Nepal	80.2	97.4
31	Bhutan	31.3	60.8
48	Pakistan	22.8	49.6
50	Afghanistan	7.2	46.0
71	India	21.9	27.2

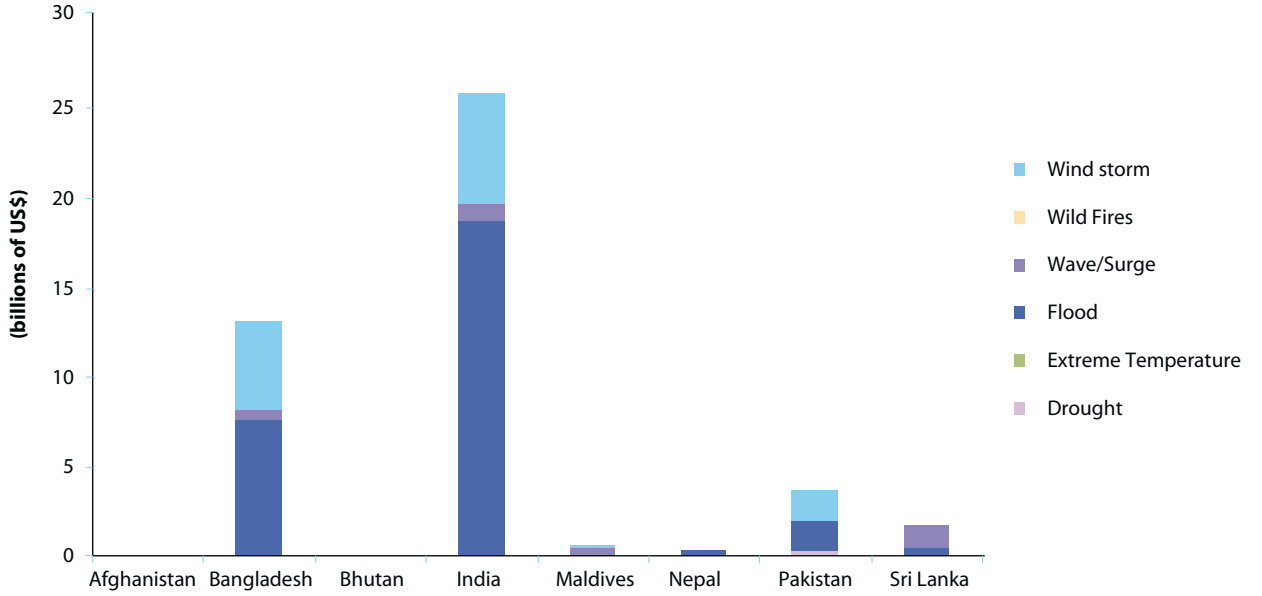
Source: World Bank 2005

a. Hazards include earthquakes.

Figure 8.3 shows the Emergency Events Database–reported costs of damage in South Asia by country and type of disaster in the period 1990–2008.[63] Floods account for the majority of damages (measured by cost), followed by windstorms. Large distributional differences are present within each country. The impact of the 2007 cyclone Sidr on the Bangladesh economy was estimated to be a modest 2.8 percent of GDP, but at a local scale several districts were much more severely affected. There are also indirect effects of floods, such as the degradation of agricultural lands and the consequent decline in their productivity, long after the floods have receded that add to the toll of natural disasters.

With climate change and rising population densities, damage and exposure to natural disasters is set to increase. Since the region shares common geological formations and river basins, natural hazards transcend national boundaries. Heavy rainfall and the high silt load of water bodies cause recurrent floods over large areas, often transboundary in nature. The floods in Bangladesh and India, for example, have their origins in Bhutan and Nepal.

Figure 8.3 Reported Costs of Damage in South Asia by Country and Disaster Type (1990–2008)



Source: Emergency Events Database (EM-DAT: The OFDA/CRED International Disaster Database) (http://www.em-dat.net).

[63] Emergency Events Database (EM-DAT: The OFDA/CRED International Disaster Database), http://www.em-dat.net.

Fiscal Impact of Disasters

Relief measures and their financing may not be sustainable in the not-so-distant future. The damages caused by natural disasters are exerting more and more pressure on development opportunities. Public expenditure is placed under stress by the repeated need for relief work in vulnerable areas. In India for instance, the direct losses from natural disasters amount to up to 2 percent of India's GDP and up to 12 percent of central government revenues (World Bank 2003). Several state governments spend significantly more on relief and damages than on their rural development programs. In the state of Maharashtra, a single drought in 2003 and a flood in 2005 consumed more of the budget (Rs 175 billion[64]) than the entire planned expenditure (Rs 152 billion) on irrigation, agriculture, and rural development for the 2002–2007 period (World Bank 2007). Oxfam (2008) estimates that between 2 and 6 percent of South Asia's GDP is lost to disasters every year.

Governments usually respond to natural disasters only in their aftermath. This is largely due to both limited fiscal resources and a lack of economic incentives to engage in disaster-mitigation strategies. Many countries depend on emergency aid and on easily available reconstruction funds from international development organizations to alleviate the impacts of disasters. This dependence can adversely affect the need for proactive disaster management. Many development programs already experience a reduction in their effectiveness. Though relief programs can be strengthened and will continue to remain a key source of aid to countries suffering from extreme natural disaster events, in the long term there is a clear fiscal and development need to strengthen climate resilience by addressing the root causes of vulnerability (World Bank 2007).

Response to the Natural Hazards Threat: From Relief to Resilience

Economic losses and loss of life from natural disasters can be reduced through a systematic approach to planning and preparation. Some South Asian countries have recently adopted disaster-management plans that focus on prevention and preparedness rather than on relief and response. Several countries have begun to develop national-level disaster-management legislation and to institutionalize national disaster-management frameworks that engage district- and state-level authorities in action planning to improve resilience to natural disasters (Box 8.1).

Recognizing these needs of the region, the World Bank has begun to engage in high-priority risk mitigation activities and to provide support for the mainstreaming of disaster-risk practices

Box 8.1 India and Bangladesh: National Disaster Management Frameworks

In India, the National Disaster Management Framework (August 2004) sets out policy parameters and provides guidelines on institutional mechanisms, disaster prevention strategy, early warning systems, disaster mitigation, preparedness and response, and human resource development.

Bangladesh has improved its ability to manage disaster risks, in particular floods and cyclones, after the cyclone of 1991 that claimed nearly 140,000 lives. This has been the result of a gradual shift from a response-based approach to one that incorporates elements of greater emergency preparedness and risk mitigation.

Pakistan has prepared a National Disaster Risk Management Framework, operational since March 2007, which serves as a vision and provides guidelines to coordinate responses across sectors and stakeholders.

[64] Indian rupees.

into the overall development agenda of client governments. Various programs and projects have been developed, such as the establishment of the new Global Facility for Disaster Reduction and Recovery, which provides annual grants of about US$4 million for the countries in the region to mainstream risk mitigation into the development process.

Strategic coordination between the disaster-risk-management and the climate-change agendas is of high importance. Many of the impacts associated with climate change alter the risk profile of existing hazards, such as floods, droughts, cyclones, and other extreme weather-related events. Adaptation measures can benefit from the practical experience in disaster management. When dealing with climate-change risks, it is important to recognize the existing vulnerability to climate variability. 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. In this context, the disaster-risk-mitigation and climate-adaptation agendas require an integrated approach.

Maintenance of risk-mitigation investments is critical for many protective infrastructures but is often overlooked. It has become increasingly apparent that expensive disaster-prevention infrastructure often fails due to lack of maintenance. Reasons for this include a shortage of human resources available for maintenance tasks, inadequate levels of training in maintenance management, and a lack of beneficiary ownership and accountability.

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The high concentration of risk also suggests that mechanisms are needed to either finance or transfer the financial risks of catastrophic events. How to fund the necessary response is always a key question for disaster-affected countries. There is a clear need in most cases for immediate funds that might be covered by contingency funding. The World Bank has already supported such initiatives in Colombia, Mexico, and Turkey, and similar mechanisms may be applicable to the countries of South Asia.

Key elements of the framework proposed to deal with these issues include the following:

a. Disaster-funding approaches are needed that encourage *ex ante* mitigation efforts (i.e., risk management) as well as reinforce *ex post* response capacity (i.e., coping mechanisms).

b. Three basic and interlinked building blocks:

- A formal institutional structure (disaster-management agency) to guide, support, and fund mitigation efforts and response capacity enhancement, particularly with respect to critical infrastructure and the poor.
- A national capacity to offer catastrophe insurance to better-off households and small business owners. Where insurance markets are undeveloped, this may take the form of a separately managed catastrophe pool, possibly backed by international capital (e.g., reinsurance and catastrophe bonds).

- A "visibility filter" whereby decision makers can be shown to be responding to all affected households after a catastrophe. This will often take the form of a low-interest loan facility for reconstruction costs, including the cost of any postdisaster mitigation requirements and modest relief grants.

c. Techniques are needed to identify gaps between *ex post* resource availability and postdisaster financing needs (particularly for those countries and states with concentrated and vulnerable exposures). Modern technology can enable these to be identified and appropriate ex ante funding strategies developed.

d. *Ex ante* funding mechanisms will need to be designed explicitly to support the three building blocks listed above. World Bank contingent credit and reinsurance funding instruments have already taken on this role in a number of countries subject to earthquake risk.

Role of the World Bank

The World Bank is strongly promoting a proactive and strategic approach to natural disaster risk management in the South Asia region by supporting the establishment of effective disaster risk management systems. The Bank's proposed disaster risk management framework is based on five basic pillars:

a. **Risk identification and assessment:** What is the country's hazard exposure? What are the economic and social losses? What is the probability of loss exceedance? Where is the risk concentrated?

b. **Risk mitigation:** What structural and nonstructural measures are suitable and affordable to mitigate physical damage? What are the priorities for intervention, considering risk to lives, livelihoods, and the need for emergency facilities? How best can these measures be financed and sustained?

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c. **Emergency preparedness:** Is the country sufficiently prepared to respond to emergency situations, organizationally and technically? Does the existing coordination and response mechanism function under stress? How efficiently are public, nongovernmental, bilateral, and international aid institutions integrated in the emergency response system?

d. **Catastrophe risk financing or transfer:** What is the country's financial capacity to absorb catastrophic events? Is there a funding gap? What are the most suitable financial instruments with which to address the funding gap?

e. **Institutional capacity building:** What is the country's capacity to manage risk at different levels of government? Is an institutional framework and coordination mechanism in place that allows strategic planning and decision making at the central, regional, and

local levels? Are technical, social, and economic considerations integrated adequately in the investment decision process?

The increasing frequency and intensity of natural events pose a significant threat to development and may challenge the prospects for achieving the Millennium Development Goals. The increase in surface-sea temperature due to climate change is likely to intensify tropical cyclones and hurricanes. It is imperative that the region improves disaster preparedness in order to save lives, but also that it promotes adaptation to climate-change risks. Both disaster risk reduction and climate-change adaptation have to be integrated into national planning strategies.

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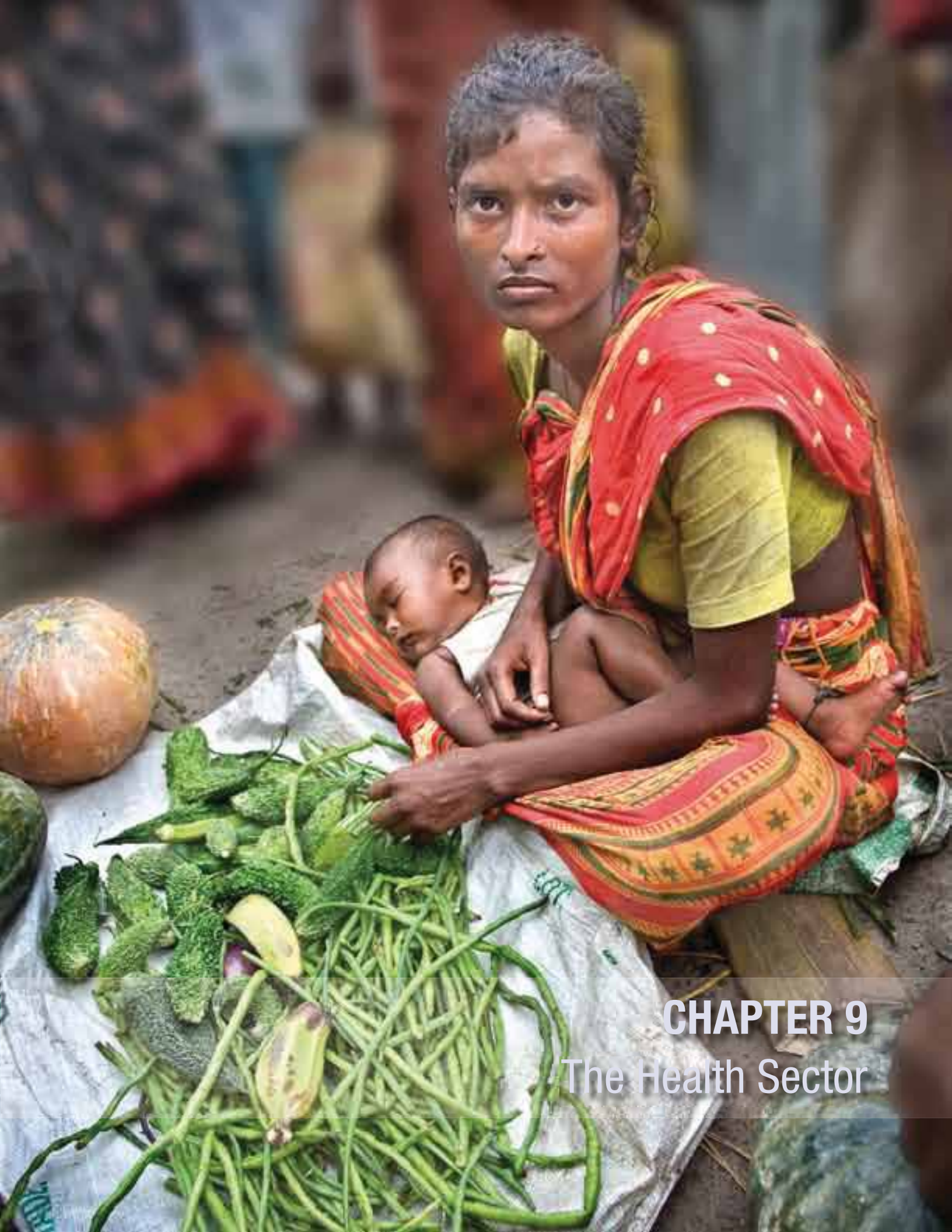

CHAPTER 9
The Health Sector

CHAPTER 9
The Health Sector[65]

Climate change is likely to affect the basic determinants of health: clean air and water, disease vectors, and the availability of food. Many major diseases are highly climate sensitive. A warmer and more variable climate increases air pollutants, which in turn lead to respiratory and airborne diseases. With likely impacts of climate change coming in the form of extreme events such as floods and cyclones, the transmission of diseases is also likely to proliferate. Climate change threatens to slow the considerable progress that has been made in combating climate-sensitive diseases.

In South Asia many of the leading causes of mortality, such as diarrheal diseases and respiratory infections, reflect the poverty that remains endemic to much of the region. For example, in areas with inadequate sanitation, diarrheal disease outbreaks are likely during times of flooding. With increased rainfall during the monsoon season, these outbreaks will become more frequent. In urban areas, an increase in air pollutants associated with rising ozone levels will exacerbate chronic illnesses such as cardiovascular disease and asthma. Climate change will likely affect both communicable and chronic causes of illness. The more prosperous parts of the region are undergoing an epidemiologic transition, with the health burden shifting away from communicable diseases toward a higher incidence of chronic diseases.

The relationship between climate change and human illness is complex, little understood, and difficult to assess. Accordingly, chapter 9 provides a broad qualitative overview of its *likely* impacts. The risks to health stemming from climate change will occur through three channels: (i) the impacts that are directly related to weather or climate; (ii) the likely impacts that result from environmental changes that occur due to climate change; and (iii) the impacts that result from consequences of climate-induced economic dislocation, environmental decline, and conflict (WHO 2005). Each of these is explored in the South Asian context in greater detail.

Impacts Directly Related to Weather or Climate

Human health impacts directly related to weather or climate include changes in the frequency and intensity of temperature extremes and severe weather events. In South Asia, this includes heat waves, flooding, and increased intensity of tropical cyclones and storm surges.

[65] Authors in alphabetical order: Michael Engelgau, George Luber, Bryan Moy, Melissa Poulsen,

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Heat Waves

As summer temperatures rise, heat waves are projected to become more common and of longer duration. This may cause an increase in heatstroke and in the incidence of cardiovascular, cerebrovascular, and respiratory diseases (Hales, Edwards, and Kovats 2003). In South Asia, heat waves are associated with high mortality rates in rural areas and, also, among the poor and outdoor laborers (Chaudhury, Gore, and Ray 2000). A large number of heat-wave-related deaths have been reported, mainly among vulnerable populations: the poor, the elderly, and laborers such as rickshaw pullers and agricultural workers (Lal 2003). A heat wave that took place in Andhra Pradesh, India, in 2003, with temperatures rising to over 48°C (118°F), caused more than 3,000 deaths (Government of Andhra Pradesh 2004).

Rising temperatures are also expected to exacerbate the existing urban heat island effect, thus increasing the vulnerability of some urban environments to heat-related mortality. The air temperature in cities can be up to 12°C warmer than that in surrounding suburban and rural areas due to absorption of heat by dark-paved surfaces and buildings; lack of vegetation and trees; heat emitted from buildings, vehicles, and air conditioners; and reduced airflow around buildings (CEIDH 2001). With five of the world's megacities and many other urban areas situated in South Asia, rising city temperatures have the potential to impact the health of city dwellers, particularly of those residing in slums, who generally are more exposed to natural elements.

Flooding

Greater intensity of rainfall events in South Asia is projected to likely increase the frequency of floods (Cruz et al. 2007). These trends are already being seen. In 2007, floods resulting from monsoon rains killed more than 2,000 people and displaced more than 20 million people in Bangladesh, India, and Nepal. In the Himalayas, the frequency of glacier lake outburst floods rose during the second half of the 20th century[66] (WHO 2005).

Flooding has been associated with direct and induced health risks. Direct risks include death due to drowning and trauma from being hit by objects moving rapidly in the flood stream (Ahern et al. 2005). Often the greatest harm stems from induced impacts. Flooding creates an environment conducive to the transmission of disease. If floodwaters become contaminated with human or animal waste, the rate of fecal-oral disease transmission may increase, allowing diarrheal disease and other bacterial and viral illnesses to flourish. Fecal-oral transmission of diseases is of particular concern in regions where access to clean water and sanitation is limited. Increases in diarrheal disease, cholera, dysentery, and typhoid are of specific concern (Morgan et al. 2005). For example, flooding in West Bengal caused an outbreak of cholera-induced diarrhea that resulted in 276 deaths (Sur et al. 2000). Numerous studies have correlated previous floods in Bangladesh and India with outbreaks of diarrhea and respiratory

[66] Glacial Lake Outburst Flood Monitoring and Early Warning System, http://www.rrcap.unep.org/issues/glof) (accessed September 9, 2008.

infections (Siddique et al. 1991; Kunii et al. 2002; Biswas, Pal, and Mukhopadhyay 1999; Mondal, Biswas, and Manna 2001). Flooding can also contribute to increased vector- and rodent-borne diseases. Stagnant water provides breeding grounds for mosquitoes, potentially aiding the spread of malaria (Ahern et al. 2005). Other studies have correlated flooding in Bangladesh and India with outbreaks of rotavirus infections (Fun et al. 1991) and leptospirosis (Leptospirosis, India, 1999; Sehgal, Sugunan, and Vijayachari 2002; Karande et al. 2003; Karande et al. 2002).

Tropical Cyclones and Storm Surges

South Asia is particularly vulnerable to cyclones, which often have devastating health consequences. (See Box 9.1.) Of all deaths resulting from the world's 35 most deadly cyclones (from the years 1584 to 1991), India and Bangladesh accounted for 76 percent (Ali 1999). Two of the world's three deadliest cyclones occurred in Bangladesh, causing 300,000 deaths in the 1970 cyclone and 138,000 deaths in the 1991 cyclone (Keim 2006). Likely increases in sea-surface temperatures are expected to increase tropical cyclone intensity and the height of storm surges in the region (Ali 1999) (Box 9.1). Although the frequency of cyclones originating in the Bay of Bengal and the Arabian Sea has decreased, their intensity has increased since 1970, causing significant damage (Ali 1999; Lal 2001; Lal 2003) (see also chapter 6).

The main health risks associated with these phenomena are drowning and the spread of diseases. The majority of deaths occur at the impact phase of the cyclone due to drowning (Keim 2006). Chronic diseases are known to be exacerbated after cyclones, as cyclone-affected populations undergo intense physical and mental stress and have limited coping abilities (Hess, Malilay, and Parkinson 2008). Unfortunately, disruptions in critical health services are highly likely following a cyclone (Keim 2006), leaving those suffering from chronic illness without care for indefinite periods of time. As in the case of flooding, other public health effects of cyclones include disease and illness associated with the loss of clean water, hygiene, and sanitation, particularly in densely populated shelters; increased pest- and vector-borne diseases; toxic exposures; and loss of shelter and population displacement that increase vulnerability to disease (Keim 2006).

Impacts Resulting from Climate-induced Environmental Changes

Other human health impacts will stem from changes in the environment due to altered climatic conditions. In South Asia, environmental changes are likely to decrease agricultural productivity and alter ecosystems in ways that will lead to a reduction in the food supply and an increase in vulnerability to outbreaks of infectious diseases, both waterborne and vector borne. The prevalence of diseases associated with air

Box 9.1 Storm Surges

Storm surges are bodies of water that are pushed toward the shore by swirling winds around a storm. The surges combine with normal tides to create the storm tide, which can increase the mean water level to heights that can impact roads, homes, and other critical infrastructure.

Additional wind-driven waves can amplify the storm tide and cause severe flooding in coastal areas, particularly when the storm tide coincides with the normal high tides. Because much of the Southern Asian coastal zone lies less than three meters above mean sea level, the danger presented by storm tides is tremendous.

Source: Federal Emergency Management Agency (FEMA): Hurricane Hazards: Storm Surge. (http://www.fema.gov/hazard/hurricane/hu_surge.shtm)

pollutants and aeroallergens is also predicted to increase with changes in the hydrologic cycle and increases in ambient temperature.

The burden of climate-related disease is greatest for the poorest populations. For example, per capita mortality rates from vector-borne diseases are 300 times higher in developing nations than in developed countries. This is due, in part, to the fact that vector-borne diseases are more common in warmer regions, but it also reflects poverty-related vulnerability. Individuals without adequate food, shelter, or heath services are obviously more vulnerable to climate-related health risks.

Waterborne Diseases

Waterborne diseases, including cholera and diarrheal diseases, such as giardiasis, salmonellosis, and cryptosporidiosis, are common and frequent. The frequency of such incidents is likely to increase in South Asia as an effect of an increase in temperature (Hales, Edwards, and Kovats 2003). Diarrheal disease is already a major cause of morbidity and mortality in South Asia, particularly among children. It is estimated that 25 percent of childhood deaths are due to diarrhea (Zaidi, Awasthi, and de Silva 2004). Diarrheal diseases are largely attributable to drinking unsafe water and lack of basic sanitation (Ezzati et al. 2004). Reductions in the availability of freshwater are therefore likely to increase the incidence of such diseases. Water shortages are already a reality due to rapid urbanization and industrialization, population growth, and inefficient use of available water (Cruz et al. 2007). The shortage of freshwater is likely to be aggravated by climate change. As previously discussed, flooding is also associated with increased incidence of diarrheal disease, particularly in regions where access to clean water and sanitation is limited: as floodwaters become contaminated with feces, fecal-oral disease transmission routes increase the incidence of diarrheal disease.

Evidence is emerging to show that cholera outbreaks are likely to increase in some areas. Phytoplankton blooms, which are supported by warmer sea-surface temperatures, provide an excellent habitat for the survival and spread of infectious bacterial diseases such as cholera (Pascual, Bouma, and Dobson 2002). Evidence also shows that El Niño plays an important role in the interannual variability of endemic cholera (Pascual, Bouma, and Dobson 2002), and annual weather patterns also influence these patterns (Box 9.2). In Bangladesh there are two peaks of cholera cases, one in the spring and a larger peak following the monsoon season. The onset of these epidemics is correlated with dry weather and warm water temperatures (Lipp, Huq, and Colwell 2002).

Vector-borne Diseases

Several tropical vector-borne diseases are highly sensitive to climate. Not only does

Box 9.2 Cholera and El Niño

A study by Rodo et al. (2002) determined a relationship between stronger El Niño events and cholera prevalence in Bangladesh over a 70-year period. The study used statistical methods to verify periods of historical cholera data dating back to 1893, enabling an examination of the effect of nonstationary interannual variability possibly associated with climate change.

Since the 1980s there has been a marked intensification of the El Niño southern oscillation (ENSO), beyond that expected from the known shift in the Pacific Basin temperature regime that began in the mid-1970s. The authors found the association of cholera incidence with ENSO in the earlier part of the study period (1893–1940) to be weak, while later in the period (1980–2001) a strong correlation emerged between intensified ENSO events and the incidence of cholera.

Source: Rodo et al. 2002

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temperature and precipitation influence pathogen development within vectors, but vectors themselves are also subject to climactic variability.[67] Given the complexity of the interactions, the relationship between climate change and human illness caused by vector-borne pathogens is difficult to assess. However, studies suggest that climatic variability and extreme weather events, likely to occur in South Asia, may increase the occurrence of outbreaks and the spread of vector-borne diseases in some areas. Climate variability that induces changes in human behavior can also alter the patterns of vector-borne diseases. For example, changes in population density, water storage, irrigation practices, land use, construction techniques, and the use of air conditioners can all vary the way in which vectors and humans interact (Gage et al. 2008). Box 9.3 uses the example of migratory birds to illustrate the complex relationships that can exist between climate, species population dynamics, and disease vectors.

The threat from malaria is likely to be the greatest concern. Malaria is already one of the most important vector-borne diseases in Bangladesh, India, and Sri Lanka. Changes in temperature and precipitation patterns have the potential to expand the geographic range of malaria into temperate and arid parts of South Asia (Hales, Edwards, and Kovats 2003). For example, in India the malaria distribution may expand to higher latitudes and altitudes. Again, the relationship between climate and disease distribution is complex: in some areas increasing temperatures may restrict malaria transmission, but the extent is not known (Gage et al. 2008).

Other diseases of concern are mosquito-borne dengue and chikungunya fever;

Box 9.3 Climate Change, Migratory Birds, and Infectious Diseases

Several species of wild birds can act as biological or mechanical carriers of human pathogens and vectors of infectious agents. Many of these birds are migratory species that seasonally fly long distances through different continents. Climate variability has been implicated in changes in the migratory patterns, reproductive penology, abundance, and population dynamics of several bird species\ and a northward expansion of their geographic range in Europe. Two possible consequences of these changes for the dispersion of pathogens and their vectors are the following:

- Shifts in the geographic distribution of the vectors and pathogens due to altered distributions or changed migratory patterns of bird populations.
- Changes in the life cycles of bird-associated pathogens due to mistiming between bird breeding and the breeding of vectors, such as mosquitoes.

Source: Confalonieri et al. 2007

[67] For example, arthropod vectors are exothermic. Thus, fluctuating temperatures impact their development and reproduction. The distribution and abundance of zoonotic hosts to pathogens is also affected by climate.

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parasitic diseases such as leishmaniasis, lymphatic filariasis, and onchocerciasis; and tick-borne diseases. These have the potential to shift geographic ranges and the timing of peak abundance. Human plague, a vector-borne disease carried by fleas, has had devastating effects in South Asia historically, but it may also be heavily influenced by climatic factors. Rainfall and temperature are likely to influence the frequency of plague in the future by affecting the spread of rodents, which carry fleas. Murine typhus—an arthropod-borne infectious disease caused by *Rickettsia typhi* bacteria—is also transmitted by fleas; its survival and development is also heavily influenced by temperature and humidity (Gage et al. 2008).

Diseases Associated with Air Pollutants and Aeroallergens

Air quality is significantly affected by weather conditions, including amounts of ground-level ozone, fine particulate matter, smoke, and aeroallergens. In urban areas, warmer temperatures may result in the production of more ground-level ozone through conversion of carbon dioxide emissions. Ozone is known to have negative respiratory effects, particularly affecting individuals with asthma. Being home to five of the world's megacities, South Asia will continue to be affected considerably by urban air pollution. Rising carbon dioxide levels and warmer temperatures have the potential to increase the amount of aeroallergens, such as pollen or spores, in the air. These airborne substances are characterized by their ability to cause an allergic response in humans (Githeko and Woodward 2003), which can in turn lead to an increase in the incidence of respiratory allergies.

Possible Impacts Resulting from the Consequences of Climate-induced Economic Dislocation

As climate change is likely to alter the environment, a growing concern will be the health consequences of social and economic dislocation. Specifically, the greatest health impacts associated with environmental decline in South Asia are likely to be population dislocation and displacement.

Population displacement is certain to occur, thus creating "climate refugees." South Asia's population is large and growing rapidly, and almost any perturbations to the environment may be cause for dislocation. Displacement may be the result of extreme weather events, such as the monsoon floods that displaced more than 20 million people in Bangladesh, India, and Nepal in the summer of 2007, or of sea-level rise. Since many cities are situated along the coasts, the coastal impacts of climate variability could result in mass displacement of urban populations.

People displaced internally or across borders are vulnerable to disease (St. Louis, Campbell-Lendrum, and Hess 2008). Displaced populations often end up living in refugee camps or urban slums; these are environments in which health suffers dramatically, as they are characterized by close quarters, poor sanitation, and insufficient food supply or livelihood opportunities. Mental health

impacts of extreme climate events and disasters present another public health challenge. The most common consequences of severe weather events, such as floods and cyclones, include anxiety, depression, and posttraumatic stress disorder (Ahern et al. 2005; Keim 2006). Although the mental health impacts of disasters are not well studied, an assessment in Bangladesh did show increased behavioral problems among children following flooding (Durkin et al. 1993). These behavioral health effects may be the least apparent, but they are among the most long-term and debilitating public health impacts of natural disasters (Ursano, Fullerton, and McCaughey 1994; WHO 1992).

Health Sector Priorities to Address Climate Change

Priorities

Because climate change is global in its impact, regional collaboration is necessary. In an economically integrated world, infectious diseases can spread rapidly, far beyond their origins. The past decade saw the reemergence and regional spread of many climate-sensitive diseases such as cholera, Rift Valley fever in Africa, and dengue in South Asia and Latin America. These outbreaks can cause major economic loss. Consequently, rapid disease-control responses and surveillance systems capable of detecting and tracking disease activity in a timely fashion will be essential. These will need to go beyond attention to infectious diseases and include monitoring of aspects of acute population migration, nutrition, mental health, air quality, and stress-related chronic disease. These surveillance and disease-control systems need agility and flexibility to respond quickly to the health effects of heat waves, flooding, and severe storms. They also need to be sensitive enough that they can detect changes in nutritional status linked to agricultural output declines and population migration.

Approaches to minimizing the likely health-related burden of climate change in South

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Asia need to focus on improving responses to ongoing issues that, in the future, will likely occur with greater frequency, intensity, and geographic range. A major component of a country's climate-change approach will be the prioritization of actions (see following section). The urgency of the problem, the country's current public health capacity, technology, and other limiting circumstances will all need consideration. Notwithstanding some successes, most of the countries in the region are now struggling with developing quality surveillance systems and provision of health services. Many issues, including higher-level ones such as migration, have challenged or slowed the development of the health sector. Prioritizing climate-change activities will need to consider this context as well as ongoing developments in other nonhealth sectors. Increases in the incidence of infectious diseases require health surveillance, preventive measures, and treatment efforts that are effective and have the capacity to deal with increased workloads expected in the health and related sectors.

Due to differences in vulnerabilities to climate-change health effects, country-specific strategies will be essential. However, all strategies will need to include health and environmental surveillance, building new systems or enhancing systems that are currently in place. It will be necessary to assess these needs and retool public and curative health-care services so they provide effective responses.

Role of the World Bank

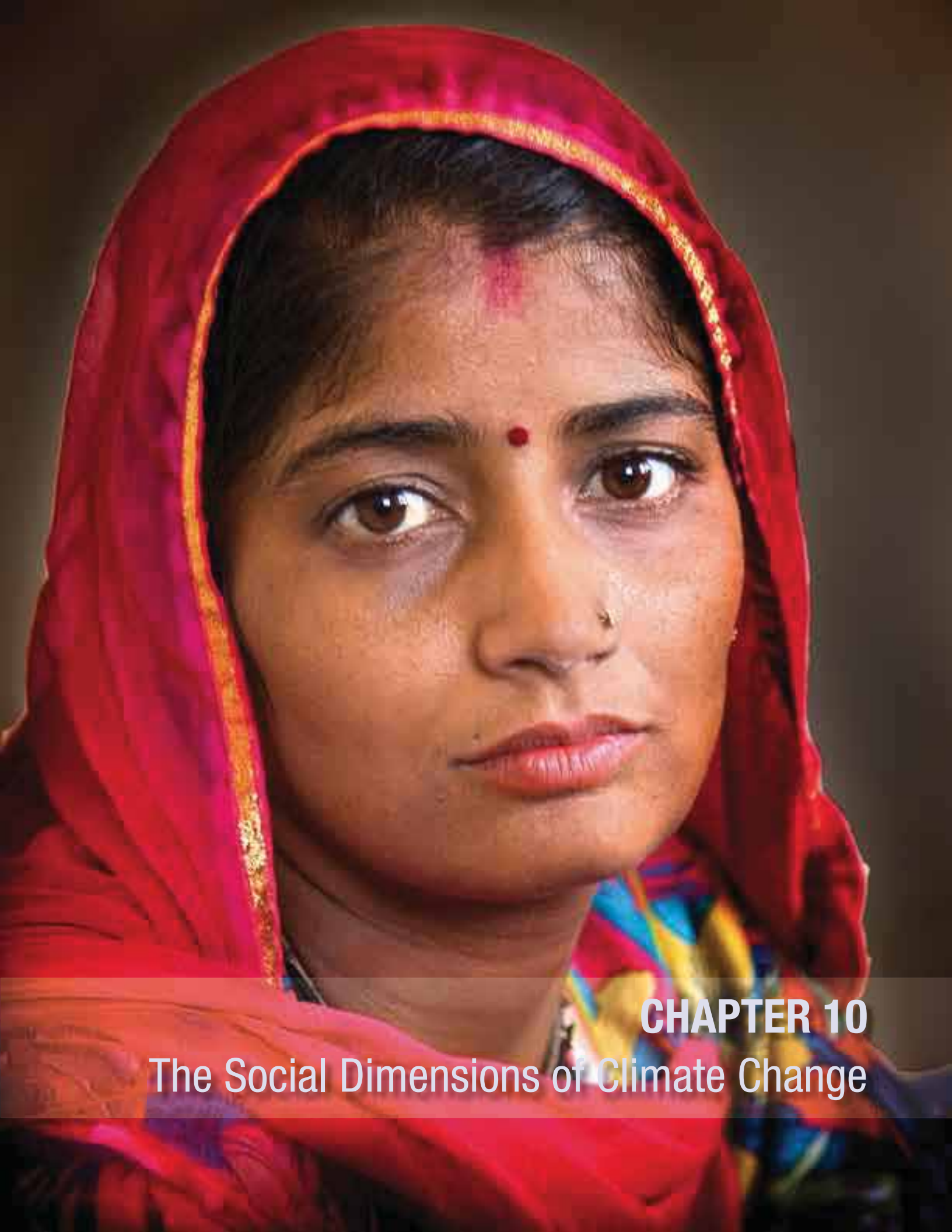
The Bank can play a role in assisting countries as they tackle likely health impacts of climate variability. The following could be priorities for the Bank:

- Playing a convening role to highlight the health dimension of the climate-change issue in the region.
- Facilitating regional- and country-level efforts aimed at developing strategies and policy dialogues.
- Providing technical assistance and knowledge products to improve health policy development.

Table 9.1 presents an action matrix for a health sector response to climate change in South Asia.

Table 9.1 Action Matrix for Climate Change in South Asia

Activity	Purpose
Awareness of the health implications of climate change	To improve policy and decision makers' understanding of the implications of climate change and the need for strategic planning
Disease surveillance	To improve government's ability to detect and monitor injuries, environmental exposures, infectious diseases, and chronic diseases that are sensitive to climate change
Response capacity	To improve the population-base public health awareness, interventions and health system capacity for climate-change-sensitive issues and diseases
Assess current and future impact of climate change	To assess current health burden due to climate change and to project it into the future in order to inform policy directions
Engage in a Country and regional approach	To develop a plan with short-, medium-, and long-term country strategies and to integrate with regional strategies



CHAPTER 10
The Social Dimensions of Climate Change

CHAPTER 10
The Social Dimensions of Climate Change[68]

The Human Face of Climate Change

Climate change could be the defining human-development challenge of our time. The likely impacts of climate change threaten to make it more difficult to reduce poverty and to stall the hard-earned progress made in achieving the Millennium Development Goals (Box 10.1). In South Asia, the early signs of dangerous climate variability are already threatening the lives, livelihoods, and health of millions, especially the poor and vulnerable. Future changes in precipitation, sea level, glacial cover, and incidence of extreme events are expected to affect food security, nutrition, availability of water, sanitation, shelter, health, labor productivity, productive sectors, and household incomes. These changes may exacerbate the already low levels of human development in the region (Table 10.1).

Climate change affects everyone, but not equally. Vulnerability is dictated by both individual and social factors. The livelihood context, location, level of income, education, asset holdings, gender, age, social class, and ethnicity all combine to determine vulnerability and coping abilities. Different social groups will be able to adapt and respond differently to climate variability depending on the scope and strength of their coping mechanisms, and the level

Table 10.1 Human Development and Vulnerability in South Asian Countries

Country	Daily per Capita Calorie Supply (kcal) in 1999	Population (%) Living below US$1/day (1990–2002)	HDI* Rank
Bangladesh	2,201	36.0	139
Bhutan	–	–	134
India	2,417	34.7	127
Nepal	2,264	37.7	136
Pakistan	2,462	13.4	135
Sri Lanka	2,411	6.6	93

Source: Watkins 2007

* Human Development Index

[68] Authors in alphabetical order: Nilufar Ahmed, Hari B. Dalal, Samantha L. Forusz.

of societal influence. Within social groups, too, some may be more vulnerable than others depending on their economic status, level of education, and physical location.

Those most heavily dependent on natural resources and exposed to multiple risks of climate change are the most vulnerable—the rural and urban poor, the women, children, and indigenous peoples. As a result, they will suffer disproportionately from the expected adverse impacts of climate change. Poor women are vulnerable because of socially constructed gender roles and behaviors, while the rural poor and indigenous people, with their greater dependence on climate sensitive sectors and lower asset holdings, are more exposed to climate shocks and also have limited coping capacity. Urban slum dwellers, with poor amenities and poor access to basic sanitation, are the first to suffer from damages to assets, spread of disease, and loss of lives as the incidence of flooding and other extreme events become more prevalent in the future.

Vulnerable Groups to Climate Change

The likely impacts of climate change will not be gender-neutral. Climate change affects women and men differently because of differential access to resources and economic opportunities. The women's labor force participation rate in South Asia is among the lowest in the world and varies between 7 and 40 percent. Wage disparities are also striking. On average, women earn 30–50 percent

Box 10.1 Potential Impacts of Climate Change on MDGs

Millennium Development Goal	Examples of Link with Climate Change
Goal 1: Eradicate extreme poverty and hunger	• Climate change is projected to reduce poor people's livelihood assets such as health, access to water, homes, and infrastructure. • Climate change is expected to alter the path and rate of economic growth due to changes in natural systems and resources, infrastructure, and labor productivity. A reduction in economic growth directly impacts poverty through reduced income opportunities. • Climate change is projected to alter regional food security. In Africa, in particular, food security is expected to worsen.
Goals 4, 5, and 6: Health-related goals: • Combat major diseases • Reduce infant mortality • Improve maternal health	• Direct effects of climate change include increases in heat-related mortality and illness associated with heat waves (which may be balanced by fewer cold-related deaths in winter in some regions). • Climate change may increase the prevalence of some vector-borne diseases (for example, malaria and dengue fever) and vulnerability to water-, food- or person-to-person borne diseases such as cholera and dysentery. • Children and pregnant women are particularly susceptible to vector- and waterborne diseases. Anemia—resulting from malaria—is responsible for 25 percent of maternal mortality. • Climate change will likely result in declining quantity and quality of drinking water, which is a prerequisite for good health, and it may also exacerbate malnutrition—an important cause of ill health among children—by reducing natural resource productivity and threatening food security, particularly in sub-Saharan Africa.
Goal 2: Achieve universal primary education	• Links to climate change are less direct, but loss of livelihoods and assets (social, natural, physical, human, and financial capital) may reduce opportunities for full-time education in numerous ways. Natural disasters and drought reduce children's available time (which may be diverted to household tasks), while displacement and migration can reduce access to educational opportunities.

Millennium Development Goal	Examples of Link with Climate Change
Goal 3: Promote gender equality and empower women	• Climate change is expected to exacerbate current gender inequalities. Depletion of natural resources and decreasing agricultural productivity may place additional burdens on women's health and reduce time available to participate in decision-making processes and income-generating activities. • Climate-related disasters have been found to impact more severely on female-headed households, particularly where they have fewer assets to start with.
Goal 7: Ensure environmental sustainability	• Climate change will alter the quality and productivity of natural resources and ecosystems, some of which may be irreversibly damaged, and these changes may also decrease biological diversity and compound existing environmental degradation.
Global partnerships	• Global climate change is a global issue and response requires global cooperation, especially to help developing countries to adapt to the adverse impacts of climate change

less than men. Though primary school enrolment has increased, gender parity dropout rates for girls across the region are higher than those for boys; and literacy rates of women are lower than men's. Low levels of education, poor health, and limited access to resources and employment not only depress women's quality of life but also limit productivity and hinder and growth.[69] The so-called benign neglect of girls has led to large gender-based health disparities. Female child mortality rates are typically high across South Asia (see Table 10.2). This is a consequence of nutritional deficiencies, lack of preventive care (specifically immunization), and delays in seeking medical intervention (Fikree and Pasha 2004). Contrary to global norms, in some states in India and Pakistan, there are fewer women than men. Climate-induced shortages of resources would likely accentuate these prevailing inequalities, suggesting an urgent need to address the underlying socioeconomic drivers of gender disparities.

Climate change would place additional burdens on women by altering the roles and tasks they perform. Low-caste, tribal, and poor rural women that depend on the natural environment for water, fuel, fodder, and food are the ones that would be most affected by climate-induced changes. As crop yields decline and natural resources become scarce, women's workloads increase, jeopardizing their chances to work outside the home or attend school. In times of drought, they will also have to spend more time performing another typical female responsibility: carrying, purifying, and supplying the family's water.

Rural women are also disproportionately affected by natural disasters. In natural disasters female mortalities vastly outnumber those of males.

Table 10.2 Probability of Dying under Age 5 (per 1000)

Country	Male	Female
Bangladesh	71	73
Bhutan	93	92
India	87	95
Maldives	38	43
Nepal	81	87
Pakistan	105	115
Sri Lanka	20	16

[69] Girls are married off at a young age and about 50 percent have their first child by age 20. In many parts of the region—notably India and Bangladesh—dowry puts pressure on families of girls to marry them early, leading to a preference for sons. In some countries, deaths of women associated with childbirth are among the highest in the world. Contrary to demographic norms, more girls than boys die at a young age in some countries. Legal and judicial systems, as well as law enforcement mechanisms, have failed to address the high incidence of violence against women in both private and public domains.

Women accounted for 90 percent of the 140,000 people killed in the 1991 cyclone in Bangladesh. Social exclusion makes women more vulnerable to natural disasters. Cultural and behavioral norms often restrict women's mobility, while economic inequality such as the lack of assets, shelter, and resources make them more susceptible to disaster-related physical impacts. Effective adaptation strategies would need to address these fundamental gender disparities.

The rural poor whose livelihoods are based on agriculture will be directly impacted by climate change. Recent research suggests that by the middle of the 21st century, the output of major crops in Central and South Asia could fall by as much as 20–30 percent in some scenarios. The yields of key cash crops such as tea, rubber, and coconut would also be adversely affected, though the magnitude is unknown (MENR 2000). The consequences would be particularly severe for women and children. Through much of South Asia, custom dictates that male members of the household are favored in the distribution of food, suggesting the possibility of increased nutritional deficiencies amongst women and children. This cultural phenomenon is responsible for chronic nutritional deficiencies among women. For example, in Bangladesh the nutritional intake of women is 88 percent that of men. In Nepal, approximately, 28.7 percent of rural women have a body mass index below the cut-off point and 60 percent of women in the region suffer from anemia (IFAD 2000). The prevalence of anemia in women ages 13–39 years is the highest in South Asia (see Table 10.3). The likely impacts of climate change could exacerbate the inequalities in food consumption.

In semi-arid areas of South Asia, households dependent upon pastoral lands for livelihoods face the threat of food and water insecurity and malnutrition. Loss of soil moisture due to temperature increases and inadequate precipitation will reduce water supplies and intensify foraging and grazing activities that degrade soil quality and land productivity. The drylands of Pakistan, India, and Afghanistan are most susceptible to the risks of more intense drought and desertification. Even moderate growth in population will increase the competition for scarce water and pasture resources. In other areas, new disease burdens could be brought by higher temperatures and more variable rainfall patterns. The incidence of climate-sensitive diseases such as malaria is already high and could emerge as leading cause of child mortality in the future.

Table 10.3 Prevalence of Anemia in Women Ages 13–49 Years, 1992

Region	Nonpregnant (%)
Sub-Saharan Africa	40
Near-East and North Africa	31
South Asia	**64**
South-East Asia	47
Middle America and Caribbean	27
South America	21

Source: Walker 1997

Michael Foley/World Bank

Indigenous people, with their dependence on forests and natural resources, are especially sensitive to climate variations. Nearly half of the indigenous peoples in the world live in South Asia (around 100 million). They are among the poorest in the world. Indigenous livelihoods and cultures are closely intertwined with ecosystems upon which they depend. They are therefore especially vulnerable to climate-induced fluctuations in ecosystem productivity. In addition, many of the proposed mitigation measures, such as the replacement of forests with plantations and biofuel crops, have the potential to undermine the customary rights to lands and natural resources of indigenous peoples.

Recognition of indigenous peoples' customary rights and their inclusion as key partners and decision makers in the design and implementation of mitigation and adaptation interventions is necessary to enhance coping capacities. They should be recognized as repositories of traditional ecological knowledge passed down over many generations and having the potential to complement and enrich existing scientific knowledge of changing climates and coping mechanisms. Interventions also need to recognize that indigenous people, with their limited human capital, may have limited capacity to adapt to changes in livelihood and economic circumstances.

In the coastal area, communities will have to confront storms of greater magnitude and frequency, rising sea-water level, and ocean acidity. Most vulnerable are those with poor climate-resistant dwellings and a high dependence upon fishing and eco-tourism. As an example, the communities of the Sundarbans, among the poorest in the region, could be trapped to a systemic cycle of poverty as seasonal flooding and natural disasters erode their coping capacities, damage their settlements, and undermine livelihoods.

Climate change may also induce forced migration from rural areas. Distress migration patterns are typically shaped by assets, community social capital, networks, and support from local institutions. The possible immediate impacts of climate stressors such as sea-level rise, increased flooding, and prolonged droughts would fall on local communities and ecosystems. Ripple effects could be felt beyond the borders of these countries if there is large-scale displacement of populations. Migration could increase tension and competition for resources in urban areas and limited space in already crowded cities. Poor households are usually forced into urban slums that are vulnerable to climate risks and where there is limited access to safe water and sanitation and high rates of child mortality. The gender dimension of migration is also significant. Male members of households are typically more mobile and leave vulnerable areas in search of employment opportunities, resulting in social disruption. In some areas the status of women is defined in relationship to their male partners. The absence of male members of the family may add to already existing barriers to accessing public services and health care facilities, often located at a distance from local villages.

Social Development Adaptation Strategies

Strengthening local governments and communities: In order to increase their preparedness to adapt and mitigate the impacts of climate change, local governments and communities will need to build their capacity to raise awareness, engage stakeholders, undertake adaptation and resilience-building programs, and deliver critical services in postdisaster settings. Robust governance mechanisms will help ensure the effective delivery of adaptive responses, strengthen a community's capacity to cope, and mitigate the impacts of a climate-related shock. Cohesive communities are better equipped to respond to external shocks, including the growing risks associated with climate change. Human society has an inherent quality to work collectively

and respond to any urgent problem or crises. As most rural societies in South Asia are community based, social capital and social networks can play a role in building climate resilience. Not only are communities with strong social capital more climate resilient, but they can also play a role in promoting local government accountability. Finding ways to strengthen communitarian responses to climate crises would provide an effective way of building climate resilience. Already existing approaches that promote decentralized, participatory decision making and accountability can be utilized for climate-change-related initiatives to strengthen social capital, improve livelihood options, and increase food security. Local institutions and other first responders will need to deliver or facilitate short-term relief and safety-net measures. Close institutional coordination and partnerships are needed among public and civil society institutions. As part of the process, poor and vulnerable groups will need to strengthen their voice and effectively use their political capital to demand access to services and support.

Promoting consultation and participation: In crisis situations, communication systems play a critical role. Poor and vulnerable people are often the last ones to understand what is happening and may be excluded for reasons of caste, ethnicity, gender, and education from public dialogue. As overreliance on one-way communication can result in the exclusion of vulnerable groups from critical information. Work on the promotion of participation among communities and civil society organizations can become a useful tool in diversifying the available avenues of communication.

Michael Foley/World Bank

Managing resettlement and rehabilitation: Estimates show that with just a one to two degree increase in temperature in a country like Bangladesh, more than 35 million people may need to be physically relocated. The same is also true for countries with expanded valleys or plains like India and to some extent Pakistan, particularly in its central province (Karachi Bay). There are a number of likely climate-change scenarios that could result in the need for mass involuntary resettlement and economic rehabilitation. Multisectoral experience in helping governments and other agencies design and implement context-specific resettlement and rehabilitation plans (under Operational Policy 4.12) across the region could be effectively applied to the resettlement and rehabilitation needs associated with climate change.

Enhancing resilience of indigenous peoples in culturally appropriate ways: Through the process of "free informed prior consultation," Social Development could be directly involved in ensuring that indigenous peoples participate in and benefit from Bank-funded operations in a culturally appropriate way. It is important that any adverse impacts are avoided, or where not feasible, minimized or mitigated. Experience in safeguarding the assets and indigenous knowledge of these communities, as well as knowledge of how these communities have adapted to changes in their external environment over time, would be a valuable resource in designing adaptation plans or interventions that will involve indigenous and traditional communities as key partners.

Filling knowledge gaps: In addition to providing operational support, there is a need to undertake research and analytical work to better assess the socioeconomic implications of climate change. Further work is needed to improve our understanding of social risk management, migration, social capital, conflict management, and so forth—areas where local and country knowledge could be effectively applied—and their impact on helping the poorest and the most vulnerable adapt to and mitigate the effects of climate change.

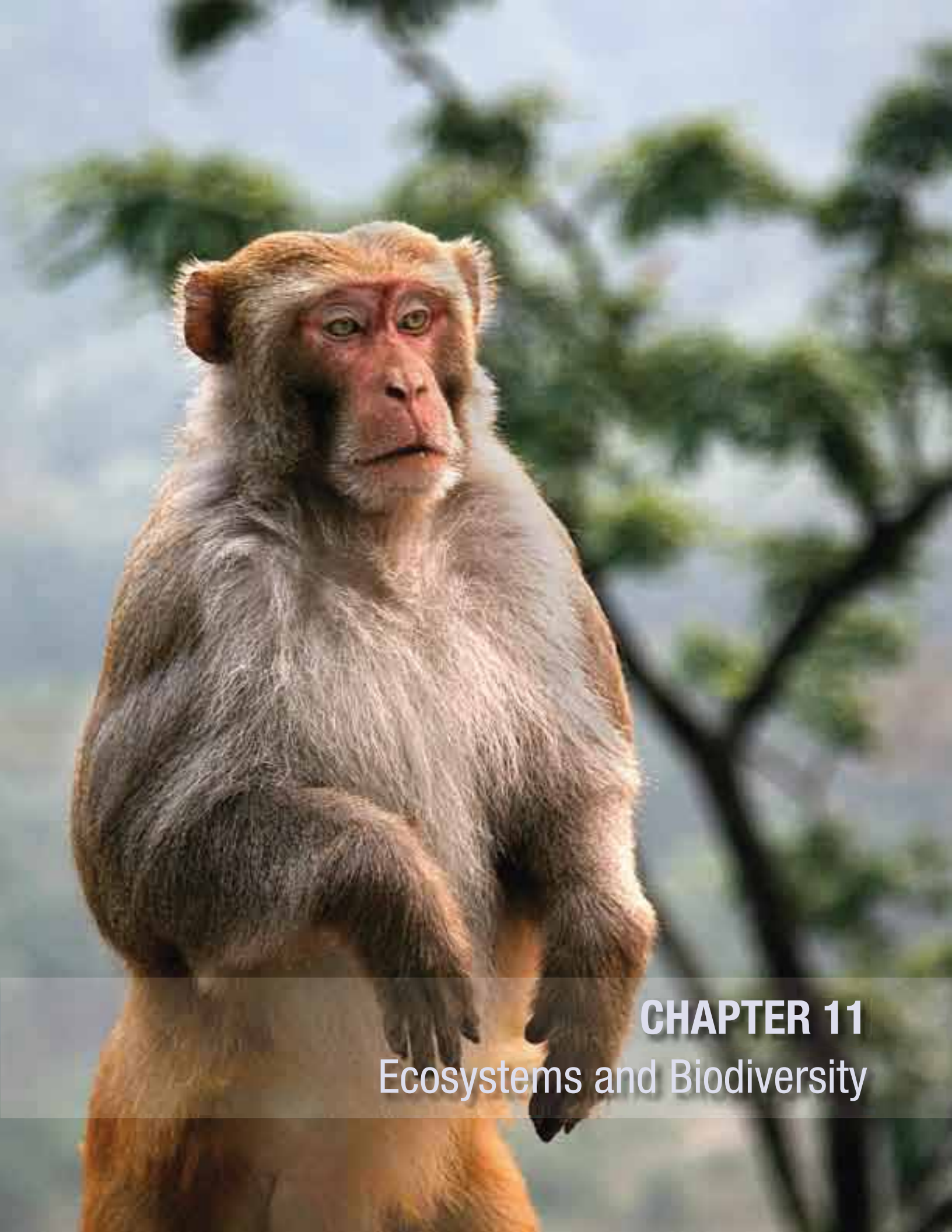
Box 10.2 Good Practice Example: Community-level Involvement in Jharkhand, India

Kanke, a small village in Ranchi District in Jharkand, India, serves as an example of how social capital aids in climate-change adaptation. In the 1970s, state government initiated a small irrigation project, which after three years of implementation, became nonfunctional. Nonparticipation of community in the planning and implementation stage of the project was cited as the main reason behind the project failure. In 2001, senior citizens from Kanke approached the state government officials and expressed a need of an irrigation project. They proposed their own plan and mechanism of water distribution. Except for the cost of a water lifting device and conduit pipes they did not seek any other external assistance. With their own local knowledge, villagers implemented the project themselves by forming a 'village development committee.' An impact study of this project shows that crop production increased and almost stabilized.

Source: Prasad et al. 2008

Table 10.4 Climate-change Risks and the World Bank's Potential Role

Risks	Priority Response
• 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, indigenous populations, and other vulnerable groups for reducing agricultural dependence. • Promotion of SHGs; enhancement of access to microfinance and banking services • Strengthening public-private partnerships and social capital of vulnerable groups, their access, and decision making • Promotion of community-based asset building and sharing of natural resources



CHAPTER 11
Ecosystems and Biodiversity

CHAPTER 11
Ecosystems and Biodiversity[70]

South Asia's Rich Biodiversity under Stress

South Asia is endowed with an exceptional array of biodiversity. The region's biodiversity is reflected in varied biomes and the wide range of habitats within its ecosystems. Its geographical expanse includes several diverse ecosystems, such as the mountains of the Himalayan Hindu Kush, the rangelands of Bhutan, the Thar Desert, the high-altitude freshwater lakes of Nepal, the Deosai plains in Kashmir, the extended contiguous mangrove swamps of India and Bangladesh, and the coral reefs and atolls of Maldives. Forests range from tropical, subtropical, and coastal to temperate, and the deserts range from hot to cold. Bengal tigers, snow leopards, sloth bears, rhinos, elephants, red panda, wild boar, hoofed animals, birds, and reptiles dwell in these forests, savannas, and deserts. The unique topography and climate has shaped the remarkable variation within the forests, rangelands, deserts, wetlands, freshwater areas, and coasts of South Asia. These ecosystems occupy about 3.6 percent of the world's area but contain 16 percent of floral and 12 percent of faunal species found in the world (UNEP 2001).

This rich ecological landscape has been integral to the lives, well-being, and livelihoods of millions of people. The ecosystems and their diversity have sustained the supply of food, water, fodder, fuel wood, clothing, shelter, medicine, and energy. Biodiversity is the foundation of agriculture and rural livelihoods. The region's livelihoods are derived in large part from forestry, fishery, and tourism, and the services performed by its ecosystems support life (through soil formation, nutrient cycling, primary production, oxygen production, and habitats) and regulate processes crucial to well-being (air quality, climate, water flow, soil retention, water purification, and biological and disease control). Biodiversity has thus been crucial to ensuring food security, income, nutrition, access to improved water, good health, safety, and the environmental sustainability of the region. The ability to adapt to changes in the environment is also determined in great part by the variation and resilience of species and ecosystems. In addition, ecosystems play a crucial role in absorbing greenhouse gas emissions.[71] Appropriate management of natural systems can therefore play a critical role in contributing to cost-effective adaptation as well as reducing greenhouse gas emissions.

[70] Authors in alphabetical order: Rahimaisa Abdula and Anupam Joshi.

[71] About 3 gigatons of CO_2 are absorbed by terrestrial ecosystems, which is about half the amount released by fossil fuel combustion.

South Asia's natural resources face tremendous pressure from rapid population growth. Economic expansion and a burgeoning population have led to unsustainable extraction of natural resources and accelerating levels of air and water pollution. Poverty, high resource dependence, and policy failures have lowered resource productivity with negative implications for development. About 10–30 percent of the region's faunal species are currently under threat of extinction. Of concern is the unsustainable resource extraction and pollution in previously remote areas with relatively large numbers of endemic species. Three global biodiversity hot spots have been identified in the region: the Western Ghats of India and Sri Lanka and the Eastern Himalayas. Table 11.1 gives a profile of the rich biodiversity of SAR countries.

Threats of Climate Change to Ecosystems and Biodiversity in South Asia

Climate change will increase the damage from current risks and present new challenges to the sustainability of ecosystems and their services. The increased precipitation (predicted for many areas) and incidence of extreme events under future climate change will magnify existing vulnerabilities. Increased incidence of rapid-onset disasters will threaten vulnerable species, while slow-onset one will prolong existing stress. Sea-level rise will induce greater flooding and exacerbate the damage to coastal ecosystems. The extent of damage from sea-level rise will span the coastal wetlands, aquifers, freshwater systems, forests, and low-lying plains, while the costs of reduced glacial cover include biodiversity loss in the mountain and low-lying ecosystems of the Hindu Kush Himalayan range. New issues will also arise from expected changes in seawater chemistry. For example, the increased acidity levels in the oceans due to warmer sea temperature will slow coral reef formation, disturb the marine food chain, and adversely affect fisheries.

Climate change will affect all ecosystems and intensify many existing stresses caused by unsustainable resource use. The changes in precipitation, sea level, seawater chemistry, incidence of extreme events, and rate of deglaciation will modify the conditions that shape ecosystems and biodiversity. These climatic changes can disrupt ecosystem functions and distort the growth, size, composition, and roles of species (IPCC 2002). The most vulnerable ecosystems are the mountain biota, rangelands, and coastal and marine ecosystems. Endemic mountain species, biota restricted to islands or coastal areas, and species with small populations, limited climatic ranges, and restricted habitat requirements are most in danger of extinction. There are more subtle impacts, too, such as the reduced capacity of ecosystems to perform sequestration that could aggravate the impacts of climate change (IPCC 2007c). There are significant knowledge gaps and a limited understanding of the impacts. Accordingly, the following sections provide an overview based largely on global assessments.

Risks to Terrestrial Ecosystems

The biodiverse forests, rangelands, and deserts of South Asia support basic human needs and

John Seidensticker/Save the Tiger Fund

livelihoods. Forest accounts for about 20–30 percent of the total land area of India, Nepal, and Sri Lanka and about 68 percent in Bhutan (Table 11.1). These are important to energy, housing, and the livelihoods of many people in rural South Asia. Savannas and dry forests are grazing areas for the region's large population of livestock, which is essential to food security and agricultural draught.

Climate change will affect the vegetation, productivity, and biodiversity of these ecosystems. Forests and rangelands that

Table 11.1 Biodiversity Profile of SAR Countries

	Afghanistan	Bangladesh	Bhutan	India	Maldives	Nepal	Pakistan	Sri Lanka
Forest Area (% of land area)	1.3	6.7	68.0	22.8	3.3	25.4	2.5	29.9
Deforestation (average annual %, 1990–2005)	2.7	0.1	-0.3	-0.4	0	1.9	1.9	1.3
Conservation Status								
% Threatened Animal Species	5.71	12.11	5.72	19.54	7.73	15.82	9.51	35.12
Critically Endangered (all species)	3	10	3	72	1	4	8	129
Endangered (all species)	5	28	12	161	3	18	16	127
Vulnerable (all species)	22	51	32	240	7	52	50	159
Endemic (all species)	1	1	3	276	0	2	3	361
Globally Threatened Species Present in the Country								
Mammals	14	23	22	86	0	31	18	21
Birds	12	23	16	73	0	27	25	15
Reptiles	1	21	0	25	2	6	9	8
Amphibians	1	1	1	66	0	3	0	52
Fish	0	11	0	35	9	0	20	29
Invertebrates	1	0	1	22	0	0	0	52
Plants	1	10	7	166	0	7	2	238
Protected Areas								
Nationally Protected Area (% of land area)	0.3	0.5	25.6	5.3	0	18.6	9.5	27.3
Total Protected Areas[a] (number)	9	26	9	718	25	30	234	278

[a] Includes all IUCN category reserves (IA, IB, II, III, IV, V and VI), Ramsar Wetlands, UNESCO-MAB Reserves, World Heritage Sites, and sites that are protected but do not fall in any IUCN categories.

Sources: World Bank, *The Little Green Data Book 2008;* 2008 International Union for Conservation of Nature (IUCN), Red List of Threatened Species (www.iucnredlist.org), accessed on January 27, 2009; World Biodiversity Database (WBDB) 2008, joint project of BirdLife International and Conservation International; and World Database on Protected Areas (WDPA) 2007, joint project of UNEP and IUCN 2007, managed by UNEP World Conservation Monitoring Centre (UNEP-WCMC) and IUCN World Commission on Protected Areas (WCPA)

receive increased precipitation relative to evapotranspiration will experience primary productivity gains. But in the long run, as critical thresholds are reached, productivity losses could ensue. Biodiversity loss occurs during the transition over the medium term and during the long-term collapse of forest types. The critical impacts on South Asia's terrestrial ecosystems include transformations in the areas supporting large habitats, such as the savanna of India, the highly endemic areas of the Hindu Kush, and the drylands at threat of desertification.

Vegetation Shifts and Loss of Biodiversity in Mountain and Forest Ecosystems

While climate change could improve forest productivity in the short to medium term, the resulting transformation of vegetation systems is likely to result in a loss of biodiversity and productivity as critical thresholds are reached. The IPCC projects that carbon fertilization will lead to net primary productivity gains in the medium term (IPCC 2007c), with the gains experienced in some forest types outweighing the losses in others.[72] Vegetation types will shift to higher elevations as a result of global warming, and some vegetation types may disappear in the process, together with dependent species and ecosystems with strict climate niches (CBD 2003; IPCC 2007c).

In India, climate change is projected to lead to loss of savanna cover. Vegetation is expected to shift toward wetter types in the northeast and to drier types in the northwest of India by 2085. This will transform the currently dominant land cover into tropical dry forest. Wildlife adapted only to the savanna landscape could be threatened by loss of habitat. Net primary productivity gains are expected for many vegetation types, but reduction in population in several species, and extinction of some species, will inevitably occur. The highly endemic areas of the Western Ghats and central Himalayas are projected to experience forest dieback and loss of biodiversity in the long run (Ravindranath et al. 2006).

In the high altitude Himalayan Hindu Kush, climate change will transform vegetation and reduce biodiversity of the mountain ranges. Climate change is expected to lead to a northward shift of vegetation and to the reduction and loss of alpine tundra cover in the dry temperate and temperate mountains of the region. The changes in precipitation in the dry temperate mountains of Pakistan are expected to expand conifer coverage at the expense of alpine vegetation even before mid-century (Ministry of Environment 2003). The upward migration of plants in the Himalayas could lead to similar reduction in alpine meadows, thus impacting the habitats of several high altitude mammals including wild sheep, goat, antelope and cattle (Garg 2005).

Changes in forest composition and density will inevitably alter the carbon budget with uncertain feedback effects on the regional climate. Shifts in and losses of vegetation cover can distort the carbon uptake of terrestrial ecosystems (IPCC 2007c). The growth in tropical forest predicted in some areas in India is expected to increase carbon sequestration in the medium run (White et al. 1999). In areas where forests shift to drier types, such as in Sri Lanka, carbon uptake could decline. The modification in carbon budget in turn transforms the feedbacks to regional and global climate (CBD 2003). Increased temperature will also raise the risks from fire outbreaks that could destroy many forest species and alter the carbon budget (IPCC 2007c). Forest fire is one of the biggest threats to the forests of Bhutan. There are on average 50 forest fires reported every year in the country. About 40 percent of its forest area has been identified as susceptible to frequent fire. Forest fires also degrade the soil, release stored carbon and emit other greenhouse gases (IPCC 1998).

[72] IPCC (2007c) predicts some reversal of forest productivity in the later part of the century.

Threat of Desertification in Rangelands and Semi-deserts

Climate change poses a threat of desertification in drylands expected to undergo increased aridity. South Asia's arid and semi-arid rangelands provide livelihood for millions of herders and pastoralists in Afghanistan, India, and Pakistan (Ministry of Environment 2003). The deserts of the Indus Valley and Thar support population densities of about 150 per square kilometer—almost five times the global average for desert areas. Though projections of the impacts of climate change on the arid areas are uncertain, there is growing consensus that El Niño southern oscillation events in the Pacific Basin are likely to increase the incidence and duration of droughts in drylands and deserts. In most deserts and rangelands, the combined effects of higher evapotranspiration, lower precipitation, and more intense and protracted droughts will reduce soil moisture and promote desertification. Fewer flood events with greater intensity will also induce aridity as less moisture is infiltrated into soils (UNEP 2006).

Future changes will likely be most severe in desert margins and desert montane areas where the principal arid rangelands are located (UNEP 2006). The rangelands and semi-deserts of Afghanistan, India, and Pakistan are vulnerable due to the projected increase in the intensity and frequency of drought in the future. Projections suggest that the Thar Desert will expand over the coming century due to local shortfall in precipitation and increased aridity in its northeast and eastern neighboring areas (Goswamy and Ramesh 2007). Desertification has also been identified as a major threat to Pakistan's biodiversity (IUCN 2002). Deserts and rangelands fed by melting snow or ice, such as those in India and Pakistan, will be susceptible to future desiccation of rivers. As the volume of snowpack diminishes, rivers will shift from glacial fed to pluvial.

The changes in desert, rangelands, and savanna cover brought about by climate change will feed back to regional and global climate. On balance, savannas and grasslands are likely to show reduced carbon sequestration capacity given the greater loss in soil respiration induced by warming, fire regime changes, and rainfall variability. Shifts of rangelands to deserts could release stored carbon but will have uncertain effects upon regional and global climate (MEA 2005). There are, however, potential gains that may arise from enhanced woody coverage resulting from carbon fertilization. Desert albedo in areas projected to undergo greater aridity and loss of vegetation will also enhance global cooling effect (UNEP 2006). However, there are uncertainties in the feedback of desert dusts upon global climate.

Challenges Facing Freshwater and Marine Ecosystems

Freshwater and marine ecosystems are crucial to the well-being and survival of the region's population and are under threat from multiple stressors due to climate change. The water resources of South Asia are the most important economic asset threatened by climate change. They supply water to millions of people and remain an important input to economic survival and prosperity. The wetlands of South

Michael Foley/World Bank

Asia provide food, livestock grazing, fodder, fuel wood, timber, medicine, transport, energy, and outdoor recreation. Coral reefs on the other hand match tropical rainforests in biodiversity and are important sources of revenue from tourism. Coral reefs and mangroves also protect hinterlands against coastal erosion, sedimentation, floods, and storm surges. Climate change will alter these ecosystems through changes in hydrology, sea level, sea temperature, and water chemistry.

Multiple Stresses Threatening Freshwater,[73] Wetlands, and Coastal Resources

Freshwater and inland wetlands will be affected by the likely impacts of sea-level rise, glacial melt, and extreme weather events. Of all ecosystems, freshwater aquatic resources appear to have the highest proportion of species threatened with extinction by climate change (MEA 2005). Freshwater resources and species in low-lying plains can be affected by sea-level rise through saltwater intrusion and by flood through inundation. In semi-arid areas, lower seasonal stream flow and drying up of lakes can have profound effects upon biodiversity and ecosystem services (IPCC 2007c). The drying of stream beds and lakes for extended periods could reduce ecosystem productivity due to the impacts of lower oxygen levels on aquatic habitats and water quality. The endorheic lakes in arid and semi-arid areas, such as those in the deserts of Afghanistan, could disappear as a result of climate change (IPCC 2008).

Among the multiple stresses, drought presents the major challenge to the sustainability of freshwater and inland wetlands services (CBD 2003). Most delta regions in India and Pakistan, where shortfalls in precipitation and drought have already led to parchedness and degradation of wetlands, are projected to face further evapotranspiration. Climate change could erode their ability to regulate water quality and quantity (Ramsar Convention and UNFCCC 1999). The magnitude and possible timing of these impacts is unknown and suggests the need for greater research into the likely consequences of climate change on wetlands. This is of particular significance in Pakistan, where wetlands extend over 7.8 million hectares, covering about 9.7 percent of the country. The wetlands are being rapidly degraded by a host of anthropogenic pressures. Climate change can be expected to add to these.

Coastal ecosystems are vulnerable to the myriad impacts of sea-level rise. The effects of expanding sea levels are multiple and include inundation of wetlands and lowlands, erosion of shorelines, coastal flooding, increased salinity of estuaries and aquifers, changes in tidal ranges in rivers and bays, and increase in the heights of waves. High levels of global warming are expected to lead to

Box 11.1 Sea-level Rise and the Biodiversity of the Bangladesh Coastal Area

Bangladesh is particularly at risk from sea-level rise, given that its coastal zone, comprising intertidal mudflats, mangroves, and tidal creeks, covers about 30 percent of its area. These coastal ecosystems are habitat for many species, sources of livelihood for many communities, and a natural defense against storms and floods. The coastline mangroves of the Sundarbans will be threatened by the increase in inundated areas and salinity of water.

The Sundarbans supports a diversity of wildlife: Bengal tigers, Indian otters, spotted deer, wild boars, some of the largest estuarine reptiles, and endangered turtles. Moderate increases in sea level could disturb its exotic wildlife and spur conflict between human and animal. A one-meter rise in sea level, which is likely to occur by the end of the century, will lead to the disappearance of the Sundarbans and its biodiversity (IPCC 2001).

[73] Refer to chapter 6 on climate change and the water sector.

Box 11.2 Ocean Acidification and the Protective Services of Coral Reefs

Ocean acidification is another consequence of climate change that would slow coral reef formation and reduce its capacity to protect the coast against damage from sea-level rise and wave surges. The combination of ocean and atmospheric warming changes seawater chemistry and slows the calcification of corals, which could stunt the formation of the reef framework and the vertical growth of coral reefs (CBD 2003; UNEP 2008a). This would reduce the ability of the reef to prevent coastal erosion and flooding. The future degradation of coral reefs due to combined human and natural pressures is predicted to lead to the disappearance of reef-building corals as the rate of erosion exceeds the rate of calcification (CBD 2003; UNEP 2008a).

an average sea-level rise of up to 88 centimeters over the next century. This would contaminate surface and groundwater resources (Ramsar and UNFCC 1999; IPCC 2007c) and could exacerbate the damage caused by tsunamis, storms, and flooding. The low-elevation small island state of Maldives, the mangroves of the Sundarbans, and the coastal ecosystems of Sri Lanka are particularly vulnerable to these impacts (Box 11.1). Sea-level rise could also displace low-lying floodplain and swamps, submerge intertidal areas such as mudflats, and eliminate the wetland plants and animals sensitive to salinity (CBD 2003).

Coral Bleaching, Ocean Acidification and the Impacts on Marine Ecosystems

Coral reefs are exceptionally rich in marine biodiversity and play a crucial role in sustaining fisheries and low-lying coastal areas. Coral reefs, like rainforests, support complex habitat niches that host a wide diversity of species. Corals are formed through the action of living organisms, called polyps, which secrete an external limestone skeleton that constitutes the reef framework. These coral reef builders serve as the sturdy base that dissipate tidal and storm wave velocity and provide natural protection to low-lying areas. Indeed, the existence of the Maldivian islands is largely dependent on the integrity of the ring of corals that protect them from erosion and inundation.

Climate change will increase the incidence of coral bleaching. Tropical corals survive within a narrow range of water temperatures and nutrient loads (UNEP 2008a). Even an ocean warming of 1°C to 2°C can cause bleaching of coral reefs,[74] weakening the health and services of corals and dependent species and distorting the dynamics within the ecosystem (UNEP 2008a). Sustained ocean warming of 3°C to 4°C would cause large-scale coral mortality. The reestablishment of coral reefs takes centuries, and the consequences for coral reefs of climate change may be irreversible. According to the IPCC (2007d), the projected temperature rise will exceed current tolerance levels of corals in major coral biomes in the coming 20 to 50 years.

The irreversible losses to biodiversity, and the impact upon food security and livelihood, would adversely impact economic opportunities in coastal communities. Coral coverage in the Indian Ocean islands and South Asia combined has declined from more than 40 percent in 1997 to slightly above 20 percent in 2002. In areas where coral reefs have functional linkages with other ecosystems, including deep-sea fisheries, mangroves, and seabed grasses, the impact of coral bleaching will be wide ranging. The loss of biodiversity from coral bleaching and ocean acidification could translate to losses in revenue from fisheries, mangrove ecosystem productivity, and tourism.

[74] Coral bleaching occurs when the symbiotic algae in coral tissues separate from their hosts due to sustained stress. Coral can survive this condition for a short period and even restore its symbiotic algae, but prolonged stress can cause its mortality.

Glacial Melt[75] and the Biodiversity of the Himalayas

The rapid retreat of some glaciers in the Himalayas will significantly impact freshwater resources and the vast ecosystems fed by them. At the other end of the altitudinal spectrum, climate change is affecting the Himalayan ecosystem. Glacial melt will have a wide range of impacts on river systems and the biodiversity they host (WHO 2006). The effects of the drying of rivers will extend to terrestrial systems, from mountain forest ecosystem, rangelands, and low-lying wetland and other ecosystems. Glaciers supplying the river Indus and its tributaries are predicted to be particularly susceptible to climatic warming, with a rise in temperature of 3°C reducing river flow by 40 percent and seriously affecting the riverine forests, wetlands, lakes, and mangrove forests and dependent species in Pakistan. In the short run, earlier thaw in the mountains feeding the system will reduce freshwater runoff in the summer months, placing forests and other vegetation at risk from drought. The magnitude and duration of these impacts is, however, largely unknown.

Recommended Next Steps

The impact of climate change upon ecosystems and biodiversity is a key development concern that needs to be integrated in development programs and responses to climate change. Many facets of the impacts of climate change upon biodiversity and species are still unknown, and implementation of informed programs of action requires a considerable investment in knowledge building. The existing engagement on natural resource management and biodiversity conservation must be scaled up or reconfigured to take account of the many risks from climate change. Further action must revolve around the following areas:

a. **Knowledge building:** The generation of knowledge must be directed toward reducing the information gaps and uncertainties regarding the effects of climate change upon ecosystems and biodiversity and identifying national priorities for conservation. Reducing the uncertainties requires an assessment of the status and vulnerabilities of species and biodiversity to socioeconomic drivers and climate change, and the possible impediments to their adaptive migration. Knowledge management should also take stock of local knowledge of ecosystems and best practices in management. Increased scientific knowledge is also needed to better understand the ecological responses to climate change (time lag, nonlinearity in reaction, natural adaptation mechanisms, and threshold limits). Valuation of the environmental damages of climate change must be incorporated in the assessment of the cost of climate change and benefits of adaptation strategies. Efforts should also be directed toward model development and coupling to better predict the impacts of climate change upon biodiversity and its feedbacks.

b. **Management of ecosystems and biodiversity:** New approaches to the management of ecosystems and biodiversity are required to respond to the emerging threats of climate change. Ecosystem and biodiversity considerations must be integrated into climate mitigation, adaptation, and risk-management approaches. Shift from a piecemeal to an ecosystem-based approach to management and conservation of biodiversity must be considered, particularly for interdependent and complex ecosystems such as coastal ecosystems (including coral seascapes) and the Himalayan Hindu Kush, and the conservation of endangered species. Protected area networks would need to be expanded to prevent further habitat fragmentation that could hinder adaptive migration of species. Table 11.3 presents a detailed approach to protecting, upgrading, restoring, sustaining, and

[75] Refer to chapter 6.

expanding ecosystems to develop a climate-resilient economy based on sustainable use of the natural resource capital.

c. **Integration in national and sectoral development:** Ecosystem and biodiversity concerns must also be reflected in national and sectoral development. Environmentally sensitive development and poverty reduction should integrate ecosystem and biodiversity consideration in development strategies in a wide range of sectors, including agricultural and rural development, forestry, fisheries, tourism, energy, and infrastructural development. Spatial planning and coastal and upland development, in particular, must carry safeguards to maintain ecosystem connectivity and enhance climate resilience of rural communities.

d. **Financing of biodiversity conservation:** Financing is a key challenge to biodiversity conservation. Achieving sustainable finance for biodiversity conservation will involve the creation of appropriate conditions through the removal of perverse subsidies, building capacity to design and manage biodiversity-based revenue-generating activities, and expanding the funding base through a wide range of instruments, including grants from donors, debt relief, and equity and market-based instruments.

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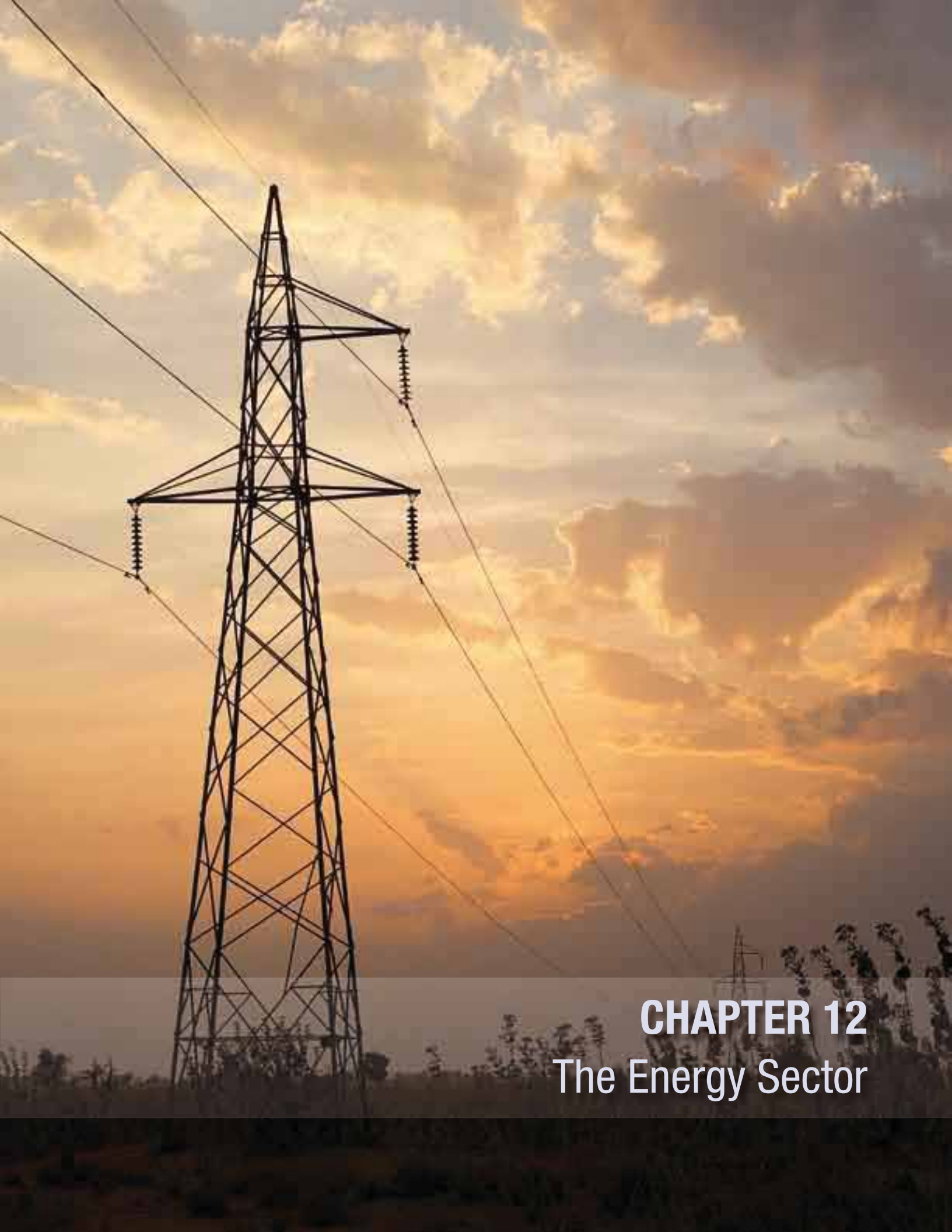
Table 11.2 Climate-change Impacts and Vulnerability Index

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, enhanced 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.								

Table 11.3 Climate-change Approach for Ecosystems and Biodiversity in the South Asia Region: The PURSE Approach

Approach	Investments required in:	Gaps	Investment support for:	
Protect	Existing public awareness network Community reserves Remaining wilderness and catchment areas Unpolluted water bodies	Lack of training on participatory resource management approaches Inadequate use of conservation planning tools, e.g., GIS Limited livelihood opportunities No long-term engagement, only project-based approaches Old staff, poor work conditions, no incentives	Improved public awareness and management skills	
			Rural livelihoods support	
			Landscape-based conservation approach	
Upgrade	Existing reserves and protected forests Community forests Fodder banks Social forestry plots Canal-side plantations	Old efforts lying in neglect—dilapidated reserves and protected forests No coordinated effort to deal with exotics and biological invasions Nontransparent resource-sharing mechanisms	Awareness generation at state level	
			Supporting local-level civil society and NGOs	
			Generating scientific knowledge and research	
Restore	Mined-out areas Degraded ecosystems (forests, wetlands, rivers, grasslands, etc.) Overgrazed pastures Wastelands Alkaline and saline soils	No regional or sector focus on restoration, poor investment support Limited knowledge base and availability of technologies International technologies not tried under regional conditions Limited or no phytoremediation	New national-level project on restoration	
			Help create database and GIS maps	
			Help develop biotechnologies	
Sustain	Existing watersheds Remaining natural habitats (mangroves, corals, homesteads, private forests, etc.) Undisturbed ecosystems	Poor PRI capacities in resource sharing Inadequate conflict resolution system and rights settlement incomplete Encroachment on natural ecosystems not addressed politically Alternate livelihoods, technological options not fully introduced	Building community ownership	
			Livelihood support in ecosystem fringe areas	
			Settlements of rights	
Expand	Forest ecosystems Wetlands (create new) Watersheds, catchments Other natural resource base	No innovative thinking for expanding ecological resource base (create forest ecosystems instead of plantations) Wetlands considered as wastelands Poor budgetary support and investments for developing ecosystem resilience	Planning Commission (India) target of 5 percent increase in forest cover (XI Plan)	
			New approaches for habitat creation	
			Mapping and database	
	Short-term		Medium-term	Long-term

Source: Developed by Anupam Joshi, World Bank staff in 2009



CHAPTER 12
The Energy Sector

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The Energy Sector[76]

Buoyant economic growth in the past decade has fuelled an insatiable thirst for energy in South Asia. Rising energy demand is driven by urbanization, industrialization, and prosperity, all of which are parts of a broader process of development that is lifting millions out of poverty. However, increased energy consumption has been accompanied by rising greenhouse gas emissions. On average, emissions have risen by about 3.3 percent annually in the South Asia region since 1990, more rapidly than in any other region except the Middle East and North Africa. Total emissions exceed 2.5 billion tons of carbon dioxide equivalents and the region has emerged as one of the major contributors to global GHG emissions. As the region strives to meet its development goals, the potential for further growth in emissions is enormous. More than 400 million people in the region have no access to electricity, more than in all of sub-Saharan Africa. How the region meets these demands will have far-reaching consequences on global greenhouse gas emissions.

Reflecting the size of its economy, population, and territory, India remains the largest contributor to GHGs in the region, accounting for about 75 percent of emissions. Consequently, greater attention is focused on India in this chapter. Though globally India is the seventh largest emitter of greenhouse gases,[77] it has low per capita emissions and low-carbon intensity. In terms of emissions per unit of GDP,[78] India remains an exceptionally low-intensity producer of CO_2 emissions. Per capita emissions in India, and the region as a whole, are low by international standards. In India, per capita energy consumption is less than 10 percent of the average of the OECD and about one-half the average for developing countries. Of the remaining seven South Asian countries, the following discussion mostly concerns Bangladesh, Pakistan, and Sri Lanka, where incremental emissions could be globally significant but where future emission paths can potentially be influenced. The energy outlook and energy options available to these countries are discussed in detail in the following section.

South Asia Region: Energy Outlook and Options in Selected Countries

India

Coal is the backbone of the Indian energy sector. India has about 38 billion tons of oil equivalent of proven coal reserves (approximately 207 years

[76] Authors in alphabetical order: Jeremy Levin and Alan F. Townsend.

[77] See Figure 2.5.

[78] When GDP is measured either by purchasing power parity or nominal exchange rates.

reserve life[79]), the third largest in the world after the United States and China. Though coal is abundant, it is of low calorie and high ash content and, therefore, highly polluting. Currently, about 70–80 percent of the country's electricity is produced from coal. Poor-quality coal, aged legal framework, low levels of plant efficiency, and an ageing capital stock combine to make the power sector highly carbon intensive. Average emissions in Indian power plants are significantly higher than the global average.[80] Transmission and distribution losses are a further drain on system efficiency and may exceed 20 percent in some states, well above global best practice (Government of India, Press Information Bureau 2001). Consequently, energy-efficiency opportunities exist to reduce the carbon intensity of power production while simultaneously increasing electricity supply.

Strategies to lower emissions by diversifying into cleaner sources of power are constrained by the country's energy resources and import possibilities. India is not well endowed with reserves of cleaner fuels such as oil, gas, and uranium.[81] Hydropower potential is significant and large in absolute terms (150,000 megawatts) but small compared to the country's vast energy needs. In addition, there are possibilities for importing about 50,000 megawatts of hydropower from Bhutan and Nepal, and perhaps as much as 20,000 megawatts of wind power from Sri Lanka. However, even when exploitation of hydropower is technically feasible, there are social and environmental concerns to take into consideration, and there remain difficulties in establishing transboundary energy trade agreements. Hydropower development is also made more complex by glacial melting, which increases the medium- and long-term hydrological risk associated with such investments.

Under most plausible scenarios, detailed assessment by India's Planning Commission suggests that coal is expected to remain the dominant fuel used for power generation, even under the most optimistic scenarios. Renewable energy sources (including wind, solar, and hydro power) and nuclear power would play a minor role in the country's energy mix (Box 12.1). For India, transformational climate-change interventions would therefore need to increase the efficiency of coal use through migration to more efficient technologies. In parallel, other future technology options such as mass solar power should be pursued, as has been suggested in the India National Action Plan on Climate Change (Government of India, Prime Minister's Council on Climate Change 2008). To be truly transformational, such supply-side interventions would need to be complemented by energy-efficiency initiatives, so that growth in overall energy demand is better managed. Box 12.2 illustrates the energy mix under alternative scenarios and reinforces the likely importance of coal in the energy mix.

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[79] Reserves/Production (R/P) ratio: If the reserves remaining at the end of the year are divided by the production in that year, the result is the length of time that those remaining reserves would last if production were to continue at that rate. BP Statistical Review of World Energy 2009, http://www.bp.com/productlanding.do?categoryId=6929&contentId=7044622, accessed October 22, 2009.

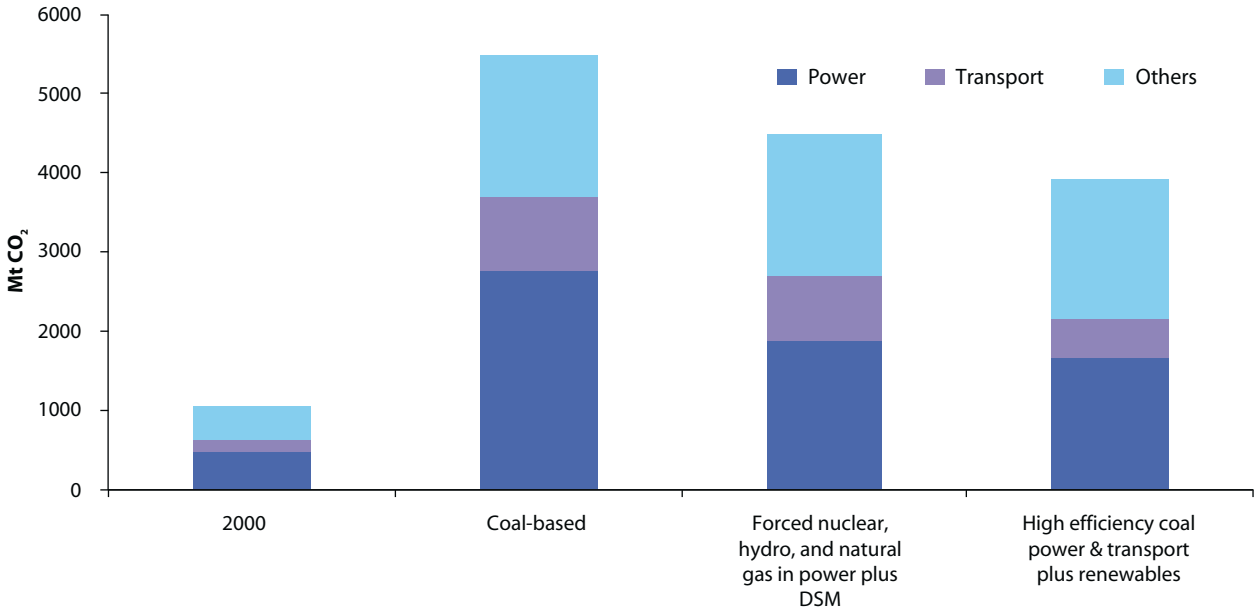
[80] With emissions from the power sector of roughly 750 grams of CO_2 per kilowatt, India's power sector is, for instance, 50 percent more CO_2 intensive than the United Kingdom's. (Government of India, Ministry of Power, Central Electricity Authority, 2007; H.M. Government, UK, Department of Trade and Industry 2007).

[81] In 2005–06 oil reserves were estimated at 786 metric tons and gas reserves are 1,101 billion cubic meters (Government of India, Planning Commission 2006).

Box 12.1 India's Supply Options for Lowering Emissions: Planning Commission Estimates

India's Planning Commission has explored possibilities for energy diversification to meet the demands of a rapidly growing economy. The figure below presents estimates for three scenarios in 2031. The economy is assumed to grow at 8 percent on average, which in turn implies more than a tripling of energy needs. In the business-as-usual scenario, more than 60 percent of generation is coal based. In this case, by 2030, India's emissions approach those of the United States today (approximately 6,000 million tons). The forced nuclear, hydro, and natural gas scenario and the high-efficiency coal, power, and transport plus renewables scenario are the most optimistic cases and are useful in illustrating limits and possibilities. These assume that all available hydropower potential (150,000 megawatts) is exploited, nuclear capacity increases at an optimistic pace, demand-side management reduces demand by 15 percent, and at least 11 percent of generation is from gas, irrespective of price differentials. Even in the most optimistic scenario, coal remains a dominant fuel, accounting for more than 40 percent of the mix, though emissions decline somewhat to about 4,000 million tons. The implication is clear: Under any plausible setup, coal is likely to dominate and other fuels will play a lesser role, even under extreme assumptions that are very favorable to the growth of those alternatives. Consequently, a clean energy effort must aim to lower emissions from coal.

India's CO_2 Projections in the Integrated Energy Policy Report



Fuel Type	Coal Scenario (million tons oil equivalent/%)	Forced Scenario (million tons oil equivalent/%)	High-efficiency Coal and Transport plus Renewables
Oil	467 (28%)	467 (34%)	406 (29%)
Gas	114 (7%)	164 (11%)	168 (12%)
Coal	1,082 (65%)	658 (45%)	573 (42%)
Hydro	0	50 (3%)	50 (4%)
Nuclear	0	89 (6%)	89 (6%)
Other	< 1	0	89 (6%)

Source: Government of India, Planning Commission 2007

Box 12.2 Emissions from Coal and Natural Gas

Addressing coal's market share is one way to lower the emission footprint of the energy sector. The table below summarizes conventional emission standards. The carbon advantage of natural gas is plainly evident, with combined-cycle plants having just more than 33 percent of the carbon emissions of a conventional coal-fired plant (assuming the conventional coal-fired plant is efficient). The advantage of supercritical and ultrasupercritical technology versus conventional coal is also evident, given India's dependence on coal. Yet with its increasing need to import coal supplies to meet growing demand, it is easy to see why India is so keen on increasing efficiency of coal use in the power sector.[82]

Technology and fuel Combinations	Kilograms of CO_2 emissions per Megawatt-hour	Annual tons of CO_2 per 1,000 Megawatts at 70% load Factor[a]
Natural Gas	600	3,679,200
Simple Cycle	360	2,207,520
Combined Cycle		
Coal	1,000	6,132,000
Conventional	900	5,518,800
Supercritical	800	4,905,600
Ultrasupercritical		

a. Load factor: A measure of the output of a power plant compared to the maximum output it could produce.

The table suggests that low-emission "near-zero" technologies will also be very attractive and will have significant carbon advantages, even compared to efficient natural gas. These technologies or approaches include nuclear and hydro power, nonhydro renewable, reduced loss during transmission and distribution, and increased energy efficiency. In all of these cases, a kilowatt-hour that is not generated from conventional coal (for the major South Asian markets, the default technology at this time) has a carbon benefit equal to 1 ton of CO_2 per megawatt-hour of generation. It should also be stressed that most of India's installed, operating coal-fired capacity is less efficient that the conventional coal baseline shown in the table. The 1,000 kilogram per megawatt-hour standard used in the table represents an efficiency of roughly 35 percent. However, in the state electricity board, there are plants operating at efficiencies of only two-thirds of that.

Sources: International Energy Agency, Energy Information Administration (US DOE), National Thermal Power Corp. (NTPC), BP Statistical Review of World Energy June 2008, World Bank estimates

Bangladesh, Nepal, and Pakistan

Because of the cost advantage of coal and the relative security of the fuel supply streams, Bangladesh, Pakistan, and Sri Lanka will increasingly see coal emerge as the front-running fuel for incremental generation of power. Bangladesh and Pakistan have substantial, unexploited coal reserves (albeit of dubious quality and difficult to extract), and Sri Lanka has unfettered access to global coal markets. The risks around investment in coal-fired capacity are perceived as being lower than those of alternative power sources, and the overall cost of the delivered power is competitive versus other options, based on prevailing market prices for coal and competing fuels. This suggests that there is a need for more active and extensive interventions to tilt the balance in favor of cleaner technologies. To the extent that these countries can delay the next generation of coal-fired plants under consideration, the carbon savings would be substantial, perhaps as much as 3 million tons per year per 1,000 megawatts of capacity, if it is assumed that the alternative to coal is natural gas.

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. Pakistan shares a land border with the world's second-largest holder of gas reserves, Iran. In Sri Lanka, the

[82] Supercritical and ultrasupercritical technologies operate at higher temperatures and pressures than conventional coal-fired technologies, increasing efficiency.

alternative source of supply would be imported liquefied natural gas. However, plans for a massive expansion of coal-fired energy are well advanced, so the prospect of reversing that decision may not be feasible, though little consideration appears to have been given to its health and environmental implications.

On the other hand, Bangladesh has significant reserves of natural gas, but exploration drilling has not kept pace with demand. Policy constraints, especially those related to pricing, are the key impediment to revitalizing exploration and production, enhancing production and reservoir management from existing fields, and reducing losses (mostly due to theft, but also to substantial amounts of leakage) from the existing gas supply network. Thus, the situation in Bangladesh is significantly different from that in Pakistan and Sri Lanka, as Bangladesh will not need large incentives from a global carbon market to inform investment decisions that choose between coal and natural gas. What it will need is simply more domestic gas development, and this remains firmly in the range of the possible, provided that the country's financial policy improves. Otherwise, the country will be forced to analyze the tradeoffs between coal and imported gas, much as Pakistan and Sri Lanka must do.

Michael Foley/World Bank

Approaches for Reducing Emission Intensity

Options for Cleaner Coal

In the immediate future, there are three main options for lowering the emission intensity of coal that are appropriate to the Indian setting: (i) rehabilitation of old plants, (ii) replacement of inefficient plants, and (iii) adoption of cleaner-generation technologies that are economically justifiable. Each of these is considered in turn:

- **Rehabilitation:** India's state electricity boards and their successor entities own and operate plants that represent more than 50,000 megawatts of generation capacity. Some of these are old, inefficient, and highly polluting. Rehabilitation of these with energy efficiency as a priority can generate substantial emission reductions. For example, plant efficiency can increase to 35 percent from 30 percent or below, and as a result, the annual CO_2 emission reduction would be more than 1 million tons for every 1,000 megawatts for a power plant that was so renovated.

- **Replacement:** Ageing coal-fired power plants with no further rehabilitation potential could be replaced by new, more efficient plants, ideally using supercritical technology, where technically and economically feasible.

- **Cleaner generation:** A favored option in India is supercritical technology,[83] based on

[83] Given the rapid development in the sector and other factors, selecting clean coal technology options appropriate to developing countries is difficult. Two recent papers (Tavoulareas 2007; Chikkatur and Sagar 2007) have identified supercritical and ultrasupercritical technologies as appropriate choices for immediate investment focus in India, based on commercial availability, suitability for Indian and imported coal, and demonstrated track records. India is pursuing this technology actively, with licensing arrangements in place and plants (such as that at Mundra, Gujarat) under development. Other technologies, such as integrated gasification with carbon capture, offer potential to take into consideration by the World Bank. Care should be taken, however, to ensure that such technologies have been fully tested and are suitable country specific conditions.

its track record internationally, availability in India, and suitability with coal streams (domestic and imported). It is likely that many such investments will be led by private sector entities or state organizations with substantial access to market financing, such as the National Thermal Power Corporation. There is scope to expand the use of supercritical technologies to other countries in the region.

Loss Reduction, Energy Efficiency, and Pricing

For South Asia in general and India in particular, there are large gains to be had from addressing loss reduction or efficiency gains. The energy that does not have to be generated due to loss reduction or efficiency gains is attractive from both the cost and the climate-change standpoints. There are large opportunities for efficiency gains and loss reduction in South Asia (Table 12.1). Much of the industrial output in the region is from small- and medium-scale enterprises that utilize outdated and inefficient technologies and processes. Cost-effective energy efficiency opportunities exist across the entire chain of modern energy production, distribution, and consumption in all South Asian countries. However, success in capturing these benefits has been elusive; many energy efficiency projects with positive economic returns remain unimplemented.

The classic barriers to increased energy efficiency include noneconomic pricing of energy (encouraging overconsumption), imperfect information, and institutional barriers. Additionally, weight is often given to reducing up-front costs instead of considering the lower recurring lifecycle costs typically available from installation of more cost-efficient equipment and adoption of more efficient processes. Energy-efficiency projects can also face higher transaction costs due to their small average size.

Table 12.1 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 plus energy-efficient brick manufacturing and wall paneling
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, solid waste management (methane capture to generate electricity)
Agriculture	Efficient irrigation pumping and efficient 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, solar panels for heating and cooking.

Finally, capital constraints at small and medium enterprises often leads to allocation of capital toward new production capacities rather than toward investments that will reduce operating costs through energy efficiency, especially if energy costs are a small component of total production costs.

The International Energy Agency has noted that more than 60 percent of GHG reductions could come from adoption of energy-efficient policies and measures. Though contested, this conclusion highlights the importance that energy efficiency can play in reducing demand and dependence on fossil fuel use, reducing levels of power shortages by capacity-constrained electric utility companies, and improving economic competitiveness, while capturing the environmental benefits to be derived from the numerous government-led initiatives currently under way. In India, the Planning Commission estimates that improving energy efficiency in industry will have the greatest impact in reducing India's CO_2 emissions. The Government of India has demonstrated its commitment to and support for improving efficiency with the passage of the Energy Conservation Act (2001) and the formation and operation of the Bureau of Energy Efficiency. Recognizing the importance of lowering demand through energy conservation and improved efficiency, the 11th Five Year Plan seeks to improve Indian efficiency by 20 percent by 2016/7, and the recently released Climate Change Action Plan of the Government of India includes a specific mission to increase efficiency through deployment of several innovative market mechanisms. Government-supported programs for efficiency have also been launched in Afghanistan, Nepal, Pakistan, and Sri Lanka.

Hydroelectricity and Regional Trade

Though India's hydropower potential is limited relative to its needs, the hydropower sector can contribute to reductions in emissions. The Bank already has a presence in the Indian hydro sector, with one project under implementation (Rampur) and two more under preparation (Vishnugad Pipalkoti and Luhri). There are also good prospects for an increased Bank involvement in financing of hydro capacity in Nepal and Pakistan.

There are significant opportunities in energy trade between the countries with a surplus of clean renewable sources of energy—hydropower in Bhutan and Nepal, and wind energy in Sri Lanka—and the energy-deficit countries of India, Pakistan, and Bangladesh. Trading this clean energy would allow climate-change-mitigation benefits to arise from reduced operation of thermal (particularly coal-fired) power plants. The improved interconnectedness and efficiency associated with this regional trade would also yield improvements in operational performance. However, given the inadequacy of existing interconnections for trading large quantities of clean energy and current shortages of power, at the present time imported power would serve mainly to reduce load shedding, and substantial benefits would materialize only over the long term.

Other Renewable Sources

The contribution of non-hydro-renewable energy in the overall mix in South Asia is likely to be small. Even if such alternatives experience vigorous growth, their contribution to mitigation of overall carbon emissions will be limited, though individual projects will be able to attract potentially significant volumes of carbon finance. More work and research will be needed to deploy viable technologies and support emerging technologies. Recognizing this need, the Government of India has recently unveiled an ambitious approach in its National Action Plan on Climate Change to raise solar power production capacity and invest heavily in research and development in this field.

Leveraging Climate-change-related Funds

Without adequate and additional funding it is unlikely that the South Asia region can achieve the transformation needed to create low-carbon economies. Ultimately, good projects will be the key, but the long delays in obtaining carbon finance (including through clean development mechanisms) are often a hurdle. The magnitude of available funds is also inadequate for the scale of the challenges in the energy sector.

Private Sector Players

The private sector will be playing a key role across the board in investing in new, clean coal plants, gas-fired plants, and renewable energy. The Clean Development Mechanism already provides, to some extent, a signal toward future prices of carbon. However, there will still be significant risks attached to private investment in clean energy technology that is not least cost or whose potential remains unproven.

Michael Foley/World Bank

CHAPTER 13
The Transport Sector

CHAPTER 13
The Transport Sector[84]

Overview of Greenhouse Gas Emissions from the Transport Sector

The transport sector is an important source of GHG emissions worldwide. However, in South Asia, its contribution to CO_2, the main GHG, has been low relative to other regions of the world. During the period 2000–2004, the transport sector accounted only for 10 percent of the region's total CO_2 emissions, while in the rest of the world it contributed to about 20 percent of total CO_2 emissions.[85] Given the region's significant population and economic size, this share implies carbon emitted from transport use per person and per unit of economic output is particularly low (Table 13.1). Between 1990 and 2005, the rate of growth of transport CO_2 emissions was the second lowest in the developing world (2.1 percent), after the former Soviet Union. While many of the developing regions have experienced an increase in transport CO_2-emissions in recent years, South Asia has managed to become even less transport-CO_2 intensive (Table 13.2) (Gorham, 2008).

There is some variation in the level of emissions among South Asian countries, with Pakistan and

Table 13.1 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
OECD North America	4,846	162
OECD Pacific	2,142	84
OECD Europe	1,839	81
Africa	203	88
Latin America	723	102
Middle East	1,502	207
Non-OECD Europe	834	106
Former USSR	980	133
Asia (excluding China)	196	57
China (including Hong Kong)	257	42
South Asia	*94*	*33*
Bangladesh	31	17
India	89	29
Nepal	31	22
Pakistan	170	81
Sri Lanka	279	68

Source: International Energy Agency

a. In 2005 US dollars.

[84] Authors in alphabetical order: Rahimaisa Abdula, Ke Fang, Roger Gorham, and Carla Vale.

[85] World Resources Institute Climate Analysis Indicators Tool (CAIT), http://www.wri.org/project/cait.

Sri Lanka being the most transport CO_2 intensive. The average Sri Lankan emits nearly 300 percent more CO_2 from transport than an average person living elsewhere in the region. In Pakistan, producing a given amount of economic output requires more than twice the amount of CO_2 emissions from transport than the region's average. On the other hand, at 6.9 percent, Bangladesh experienced the largest rate of growth in transport CO_2 emissions between 2000 and 2005 (Table 13.2).

When examined in the context of the high levels of economic growth the region has been experiencing, the low intensification rate of transport CO_2 emissions in South Asia as a whole is remarkable. The economy of the region grew at an impressive 5.3 percent per year between 2000 and 2005, a rate of growth that is second only to that of China (7.5 percent per year). However, while China's rate of CO_2 emissions from transport kept pace with economic growth (growing by 7.3 percent per year), that of South Asia grew at a paltry annual rate of 1.3 percent. This difference may reflect, to some degree, the nature of the respective economic engines fueling the growth in South Asia, and in India in particular, which represents nearly 83 percent of the region's economy. India's economic growth is powered by non-transport-intensive sectors, particularly information technology, biotechnology, and research and development, while China's is driven largely by manufacturing and production of goods for export.

Table 13.2 Growth Rate of Transport CO_2 Emissions by Region and by South Asian Country: 1990–2005 and 2000–2005

Region/Country	Annual Growth Rate of Transport CO_2 Emissions (%)	
	1990–2005	2000–2005
World	2.22	2.1
OECD North America	1.58	1.4
OECD Pacific	2.39	0.2
OECD Europe	1.58	0.9
Africa	3.59	3.8
Latin America	3.11	1.7
Middle East	4.45	5.6
Non-OECD Europe	1.97	5.7
Former USSR	–0.67	1.9
Asia (excluding China)	4.38	3.2
China (including Hong Kong)	6.46	7.4
South Asia	*2.12*	*1.3*
Bangladesh	6.86	6.9
India	1.43	1.2
Nepal	8.20	1.4
Pakistan	4.52	1.0
Sri Lanka	5.85	0.6

Source: International Energy Agency

Factors Underlying South Asia's Transport Carbon Emissions

The relatively low-carbon intensity of the transport sector reflects unique features of South Asia's urbanization and economy, including its low urbanization rates, low urban and rural mobility rates, and the labor-intensive nature of economic production. Only about 28 percent of the population resides in the cities of South Asia. Of this, 35 percent live in cities with populations less than 100,000 (Toutain and Gopiprasad 2006). Per capita trip rates, even in urban areas, are low. Labor rather than capital and energy remain the dominant input in production. Additionally, high fuel prices in the region may be having a price effect in restraining the transport-related GHG emissions from the region, but this effect is likely to be small. Rather, it is more likely that wage rates function as the primary constraint in South Asia. For example, the ratio of fuel price to per capita income in India is among the highest in the world—it is six times as high as in China and more than 55 times as high as the OECD average (Muralikrishna 2007).[86]

[86] India's and Pakistan's gasoline prices in 2007 (US$1.01 per liter) were about 15 percent higher than the world average (US$0.88 per liter).

More specifically, the total amount of CO_2 produced by the transport sector generally depends upon three main factors: (i) the amount and nature of the demand for vehicular travel, (ii) the energy intensity of the vehicles used to meet that demand, and (iii) the life-cycle carbon content of the system used to generate and deliver that energy.[87] Public policy, intentional or otherwise, can influence many of these factors in significant ways. This section briefly examines these factors in the South Asian context.

Demand for Vehicular Travel

Vehicular travel demand is best understood by subsector: urban passenger travel, interurban passenger travel, and freight transport. In urban areas, the magnitude and nature of demand for vehicular travel is influenced by the size of the urban population, mobility rates, amount of time people are willing to spend traveling, prevailing speeds on existing transport networks, proportion of desired trips that are walkable, the costs of vehicle movement and storage, and the viability of public transport or nonmotorized modes of transport.

In South Asia, the mobility rates, travel speeds, and motorization are low. According to RITES (1998), there are about 0.51 motorized trips per person in India. Prevailing travel speeds are low, as is the tolerance for long travel times. Gakenheimer and Zegras (2003) report typical speeds for urban buses of 6 to 10 kilometers per hour in many large cities. In city centers, average speeds during peak hours reach 5 to 15 kilometers per hour. The vast availability of the public transport system and low real wages also undermined the practicality of private motorized use. The high level of crowding in urban centers leads as well to a significant number of trips without the use of motorized vehicles. In general, the more centralized the population, the more feasible are walking trips.

The motorization rate, while currently low, is expected to rise dramatically in the future. India's rate of car ownership in 2000 was just 10 vehicles per 1,000 persons, compared to a worldwide average of about 113 vehicles per 1,000 persons (WBCSD 2003). Even including two-wheelers, vehicle ownership, although higher than the rates for either Africa or China, is still substantially lower than the worldwide average (WBCSD 2003). Forecasts, however, suggest a meteoric rise in vehicle ownership. Ownership of light-duty vehicles (cars and light trucks) is predicted to increase by 5.7 to 10 percent (WBCSD 2003; WEO 2007), resulting in car ownership of between 56 million and 115 million in 2030. Including two-wheelers, total vehicle stock under the WEO projection in 2030 at 295 million will overtake that of the United States. These figures predate the announcement of Tata Motors of the distribution of an affordable minicar model known as the Nano. This likely increase in vehicle penetration, even above those predicted in these early studies, will raise the trajectory of future CO_2 emissions.

Interurban travel tends to be a relatively important source of overall travel demand. Thus, it is an important submarket for consideration in any effort aimed at heading off growth in GHG emissions from the transport sector as a whole.

Michael Foley/World Bank

[87] This decomposition is a minor modification of the one proposed by Schipper and Marie-Lilieu 1999 as the "ASIF identity."

Michael Foley/World Bank

Intercity passenger transport occurs mostly via bus and rail (99 percent in 2006), and it constitutes a relatively important source of overall travel demand. Based on reported figures from Indian Railways and the domestic airline industry, there were 6.8 billion intercity passenger trips in India in 2006/2007.

Even though air travel mode shares are quite low, the potential growth of this market is of particular concern for CO_2 emissions over the long run. An analysis of Indian Railways' fuel consumption shows a CO_2 emissions factor of about 9.6 grams of CO_2 per passenger-kilometer in 2006, or about 1 kilogram of CO_2 per passenger trip.[88] By contrast, CO_2 emissions per passenger-kilometer from air transport in the United States in 2006 were 136 grams.[89] (India-specific aviation emissions factors were not available for the present report). Assuming these emissions factors are reasonably applicable in India, each air trip that could occur by rail instead of by air would reduce CO_2 emissions by a factor of 14.

While the drivers of freight transport demand may indicate the success of other desirable economic or social development policies (such as improved rural accessibility), effective policies to mitigate CO_2 emissions can focus on improving modal competitiveness. For example, in India, the government is investing in two dedicated, high-speed freight rail corridors to improve rail freight competitiveness, reduce costs, and increase reliability.

Energy Intensity of Vehicles

Energy intensity of the vehicle fleet is largely determined by four factors, each of which can be influenced by public policy. These factors are (i) the energy efficiency of newly acquired vehicles entering the fleet; (ii) the maintenance practices employed to minimize energy intensity of vehicles over their lifetimes; (iii) the profile of vehicle utilization—which vehicles tend to be used for which purposes, how intensively, and for how long—and (iv) the nature of traffic conditions on the roadways where vehicles are most predominantly used. Regretfully, there are too few data on any of these factors in the region to attempt drawing definite conclusions.

Based on available comparable data on energy intensity,[90] the extensive use of two-wheeler vehicles seems to produce the effect that energy consumption per vehicle-kilometer driven in South Asia is the lowest in the world. Fuel economy results from in-use fleet sampling showed that the vehicles in Pune, India, are less energy intensive compared to those in Mexico City, Shanghai, and Los Angeles (Table 13.3). This apparent efficiency does not reflect a fundamental technological difference among the regions; rather, it is reflective of the type of vehicle used for travel. About 66 percent of vehicle-kilometers traveled

[88] Key author's calculations from data provided on Indian Railways website, http://www.indianrailways.gov.in/deptts/stat-eco/Stat_index-06_07.htm.

[89] Key author's calculations from National Transportation Statistics (Bureau of Transportation Statistics).

[90] These data may not be a representative sample for the region, but are probably the best evidence available regarding fleet energy intensity.

Table 13.3 CO_2 Emissions Intensity (Grams per Vehicle-Kilometer) in Four Cities

Type of Vehicle	Pune	Los Angeles	Mexico	Shanghai
Two-wheeler	44	—	67	71
Three-wheeler	71	—	—	—
Bus	1,288	—	800	1,013
Passenger car	353	—	377	413
Delivery truck	876	—	—	803
All vehicles	125	249	387	400

Source: Key author's calculations from output of International Vehicle Emissions Model (University of California at Riverside College of Engineering Center for Environmental Research and Technology, based on databases compiled by University of California Riverside research team in 2004)

— Not available.

in Pune occurred on two-wheelers, while only 20 percent and 2 percent occurred on two-wheelers in Shanghai and Mexico City, respectively. Passenger cars accounted for 71 percent and 95 percent of vehicle-kilometers traveled in Shanghai and Mexico City, respectively, compared with only 14 percent in Pune.

The data available on fuel efficiency for new vehicles does not lend itself to international comparisons because of methodological differences. It is known, however, that fuel economy standards (or CO_2 emissions standards) for new vehicles have not yet been adopted by any country in South Asia. They are, however, under active consideration in India.[91]

While vehicle maintenance is a critical factor in the fuel efficiency of the in-use fleet,[92] the extent to which such maintenance practices are carried out in South Asia is unknown, and more research is needed. The factors that affect fuel economy that are most often cited include keeping tires adequately inflated and aligned, checking and replacing air filters regularly, changing oil and oil filters regularly, keeping the engine lubed, and avoiding aggressive driving practices, particularly heavy accelerations and breaking. Given the high ratio of fuel prices to per capita income cited earlier, however, it would be expected that such practices are widespread. There are also few data available regarding the profile of vehicle use in South Asia. Specifically, the usage patterns of older vehicles relative to newer vehicles as the vehicle fleet is expanded, and the amount of annual kilometrage of older vehicles relative to newer vehicles, are of interest.

Finally, the behavior of traffic streams in which vehicles operate also determines the overall fuel intensity of the vehicle fleet. As is well known, South Asian cities are characterized by high traffic congestion and lower-than-average road conditions, both of which negatively affect fuel intensity. In rural areas, paved roads are more the exception than the rule. Fuel economy is linked both to average speeds and to the relative proportion of acceleration to steady-state driving over a given distance. The more variable the travel speed, the higher the fuel consumption, all else equal. While fuel intensity and CO_2 emissions are lower at higher speeds, simply adopting a policy of facilitating higher-speed travel would induce mode switching and potentially additional trip making as well, thus rendering walking and cycling dangerous. This induced travel could substantially offset any fuel intensity improvements from improved traffic conditions.

Fuel Carbon Content

In the near term, utilization of bio-fuels, particularly ethanol and biodiesel, holds the most promise for affecting life-cycle carbon content of fuels used in the sector. One set of estimates of emissions factors for Indian production

[91] The effort is being led by the Petroleum Conservation Research Association, but the time frame for development of such standards is unclear.

[92] A recent study carried out by the Automobile Research Association of India on the Indian vehicle fleet revealed that maintenance seems to improve fuel economy between 2 and 19 percent, depending on the type and model year of the vehicle (Marathe and Chaudhari 2007).

techniques is shown in Table 13.4. The emission factors suggest that adding a 5 percent ethanol blend into gasoline would reduce CO_2 emissions by about 3 percent, and a 20 percent biodiesel blend would reduce CO_2 emissions by about 11 percent. Current levels of ethanol production in India would be sufficient to cover the needs in the domestic market to achieve the 5 percent ethanol blend proposition (the need has been estimated at only 700 million liters while average output per year is 1.9 billion liters).[93]

Whereas India has become one of the world's largest ethanol producers, its production capacity for biodiesel is yet to be developed. Acknowledging this need, the Government of India has pursued an ambitious National Biodiesel Mission since 2003. The objective of this mission is to supply 20 percent of national diesel demand with domestically produced biodiesel, primarily from *Jatropha*. As a desert-blooming plant, *Jatropha* would be an attractive option if it does not compete with food products, and it can be cultivated on barren marginal lands of limited ecological value. Problems arise when biodiesels begin to compete with food crops for land, water, and other inputs. Based on a demonstration phase begun in 2003, it was estimated that production costs of *Jatropha*-based biodiesel would be about US$0.47 per liter (Gonsalves 2006), though this may have been based on optimistic assumptions about production costs of *Jatropha* seed oil (Mohan and Kumar 2005). Under a policy established in 2007, state-owned distribution firms are required to purchase biodiesel at a fixed price of about US$0.68 per liter, but there is a need to be mindful of the risks associated with biofuels competing with food crops and livelihoods (Kukrika 2008).

Table 13.4 Estimates of Life-cycle Carbon Emissions from Select Conventional Fuels and Biofuels

Fuel	Life-cycle Carbon Emissions Factor (grams/kilometer)
Conventional gasoline	230
Conventional diesel	145
Ethanol (molasses derivative)	75
Biodiesel (*Jatropha* derivative)	65

Source: Gonsalves 2006

[93] This output is almost entirely produced from molasses, a by-product of sugar production. If crop sugar itself were used directly in ethanol production, annual output is estimated to be about 2.3 billion liters (Gonsalves 2006).

Future Challenges

While the transport sector has been a relatively small contributor to South Asia's CO_2 emissions compared to other regions, the rapid pace of urbanization and likely acceleration of motorization trends present a threat to mitigation efforts in the future. Urbanization, while low compared to other regions, is proceeding at a fast pace, and the mobility demanded by new urban populations serving the new information economy in rapidly transforming cities such as Bangalore, Hyderabad, and Mumbai, is indicative of the looming challenge to future mitigation. India has already 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 through the Jawaharlal Nehru National Urban Renewal Mission,[94] preparation of a nationwide demonstration Sustainable Urban Transport Program, and development of ambitious bio-fuel goals. The motorization in the region has long been predicted and is well documented.

[94] Under this program, the national government provides 35 percent of infrastructure investment funds to cities with more than 4 million people; 50 percent of such funds to cities with more than 1million; and 80 percent of such funds to certain enumerated cities with fewer than 1 million. In all cases, the cities must undertake certain reforms, develop a city development plan if they do not already have one, and finance the remainder of the investment with a combination of state, city, or outside resources (such as development finance).

Current policy measures and initiatives, while commendable, may not be sufficient to address the impending increase in transport carbon emissions. Whether the various initiatives and measures being put in place by national and local governments will be sufficient to keep transport CO_2 emissions restrained in the future is an open question. The demand for vehicular travel was forecast to be high even before the announcement of plans to build and market small, low-cost cars in India. Even more aggressive measures than those already under way may not be effective in maintaining low transport emissions if motorization rates accelerate precipitously as a result. The focus would need to be on the energy efficiency of the fleet and integrated planning measures.

Integrated urban transport planning will be key to achieving sizable mitigation in the transport sector. According to a study carried out by the World Resources Institute's Embarq Center in cooperation with the World Bank during 2007, a policy scenario that emphasized both developing integrated public transport systems—including bus rapid transit and harmonizing transport and land-use development—and engaging in rather aggressive transport-demand-management strategies was found to lead to the lowest level of CO_2 emissions growth through 2030, compared with market-based energy-efficiency initiatives and a standards-driven clean two- and three-wheeler scenario. In the integrated urban transport scenario, total transport-related CO_2 emissions were still projected to increase by a factor of nearly 5 (i.e., 39 percent less than the business-as-usual scenario), and per capita transport-related CO_2 emissions by a factor of 3.4, but these increases were the lowest of the scenarios (Box 13.1). The implication is clear. For the short term policies that target fuel efficiency are vital. For the long term integrated transport systems that include bus rapid transport, land-use policies and aggressive demand side management will be needed to curb the growth of transport related emissions. Ultimately, new technology will be required to render clean energy transport carriers more economic.

Box 13.1 Scenario Assessment of Future Growth for the Transport Sector in India and the Impact of Nano Distribution on Greenhouse Gas Emissions

The study, carried out by Embarq and the World Bank in 2007, defined four scenarios for potential development and growth of the transport sector. They are the following:

i. **A baseline scenario ("business-as-usual" or BAU)**, whereby projections of GDP are used to forecast projections of vehicle ownership; vehicle ownership rates at different levels of GDP are assumed to be the same as those observed in the Republic of Korea over the past two decades; two-wheeler ownership rates continue at the same trajectory; and infrastructure (or lack thereof) is not considered a constraint on this level of ownership.

ii. **An energy-efficiency scenario (EF),** whereby "higher fuel prices and taxes drive consumers to both smaller and more efficient cars." Those taxes are assumed to be the rates that presently characterize Japanese policy. These prices drive not only choice of cars but also the extent to which they are driven.

iii. **A clean two- and three-wheeler scenario ("two-wheeler world" or TWW),** in which Indian policy focuses on developing very clean two-wheelers in recognition of the enormous difficulties in transforming its infrastructure to one that accommodates the large growth in passenger cars assumed under the baseline scenario. Under this scenario, use of public transport grows marginally faster than in the base case, and growth in car ownership grows slower than in the base case.

iv. **An integrated urban transport planning approach,** in which cities focus on developing integrated public transport systems, including bus rapid transit, coordination with land use development, and engagement in rather aggressive transport demand management strategies.

In response to the announcement of the production of the Nano by Tata Motors, and a competitor by the Renault-Nissan-Bajaj consortium, an additional scenario, "**Nano World**," was added to the repertoire.

Tata Motors announced in February of 2008 that it would begin producing and selling a minicar branded the Nano for the South Asian market. This car would sell for Rs. 100,000—about US$2,500—per vehicle, making it the least expensive car on the market. Its price point would make it about half as expensive as its nearest competitor, Suzuki's Maruti 800, currently the top selling car in the Indian market. It has already set the stage for a price war and marketing war in the Indian car market. Renault-Nissan recently announced a partnership with Bajaj to produce a competitor to the Nano—the ULC.

The halving of the cost of owning a car will have huge implications on India's, South Asia's, and, indeed, the world's climate-change footprint in the coming years. In fact, the penetration of the Nano into the South Asian vehicle market could swamp the combined effects of any of the measures discussed in this chapter, notwithstanding the relatively high fuel economy of the Nano. Indeed, that fuel economy, anticipated to be 22 kilometers per liter (city) and 26 (highway), would presumably be offset somewhat by additional driving that would not have occurred were people driving lower fuel-economy cars.

Opportunities for World Bank Engagement

The World Bank could propose a multipronged approach, as summarized in Table 13.5. The Bank's comparative advantage probably lies in providing substantive support for the kinds of policies envisioned in the integrated urban transport planning scenario described earlier. Specifically, its comparative advantage, through technical and financial support, probably fits most squarely with the following types of measures:

- **Support for public transport enhancement and integration:** Public transport must be seen as a viable alternative for different segments of the population, particularly those who might otherwise use cars or two-wheelers. To engage in such support, the overall emphasis should be on network connectivity and integration; the types of measures that are specifically needed will depend on local circumstances. The Sustainable Urban Transport Project in India, supported by the Global Environment Facility, is an early example of this type of support.[95]

Michael Foley/World Bank

- **Support for more aggressive transport-demand management:** While often politically unpopular, aggressive transport-demand management will increasingly be a necessity to grapple with the kinds of challenges South Asian cities will face over the next several decades. Transport-demand-management measures include strategic use of parking charges and parking-management rules to discourage use of private vehicles

[95] The total GEF grant proposed for the project is US$25 million, which will be complemented with a grant of US$150 million from the Government of India, state governments, and implementing agencies, along with a US$200 million investment loan from the World Bank, implemented over a four-year period, starting from 2009. The project's objectives are (i) to strengthen capacity of the national government, as well as participating states and cities, in planning, financing, operating, and managing sustainable urban transport systems; and (ii) to assist states and cities in preparing and implementing demonstration "green transport" or "GEF-supportable transport" projects (GT projects).

for commuting to work or school; control of traffic flow in such a way as to prioritize high-occupancy vehicles, particularly public transport; employing congestion charges for particular facilities or in dense traffic zones to keep traffic flowing without inducing additional travel; and vehicle pricing regimes that are oriented toward use rather than fixed periods of ownership, such as pay-as-you-drive vehicle insurance or annual registration fees linked to recorded kilometrage of vehicles. Because these kinds of measures affect public allocation of road space, they create "winners and losers," but the latter tend to be more vocal and strident in expressing their opinions to policy makers. Voluntary policies that target fuel efficiency could provide the first stepping stone to pave the way for more robust measures.

- **Improved support and priority placed on long-range urban planning,** particularly integration of land use planning, facility siting, and transport network developments: Engagement would require closer cooperation among various sectors in the World Bank.[96]

The Bank could also provide expertise and policy clarity throughout the region. This would involve identifying the resources needed to allow more concerted engagement in ongoing processes, such as the Clean Air Initiative for Asian Cities, or for organizing events to help disseminate best practice. It will need to engage counterparts at national and subnational levels, particularly in cities, given that motorization and policies will have their loci primarily at the city level. Again, the GEF Sustainable Urban Transport Project could provide a model for the type of engagement necessary.

[96] As was expressed recently in a Brown Bag roundtable on this subject, this emphasis probably means that staff of both the urban and transport sectors will need to leave their comfort zones.

Table 13.5 Viable Short- and Medium-Term Policies to Reduce CO_2eq Emissions from Transport in South Asia

	Reduce the Demand for Vehicular Travel	Reduce the Energy Intensity of the Vehicles Used
• CO_2 emissions tax		
• Transport sector participation in a cap-and-trade regime		
Transport Sector as a Whole	• Shift the lifetime costs of vehicle ownership from time-to use-basis as much as possible	• Fuel economy or CO_2 emissions standards for vehicles entering fleet beginning with voluntary standards
	• Invest in viable public transport networks and ensure that they are competitive with private vehicles in terms of frequencies, travel time, and cost (e.g., bus rapid transit, metro, rail, where appropriate)	• Develop scrap programs to target older and inefficient vehicles and tie these programs into labor market development programs whereby former owners have alternatives to simply buying another vehicle • "Feebates" and other incentive mechanisms to encourage purchase of fuel-efficient cars (such as hybrids) without further incentivizing motorization
Urban Passenger Transport	• Coordinate land use with public transport networks by focusing development on corridors and at nodes, and mixing primary land uses where possible; coordinate and think more strategically about facility siting and land use change relative to transport networks; use value capture of the one to help finance the other • Encourage cycling and walking by creating favorable conditions for both. This means focusing on facilities, motorist behavior, and public attitudes • Use network, parking, and vehicle pricing to incentivize travel in vehicles with higher occupancy (i.e., transport demand management) • Where and when appropriate, limit access to key activity centers of city by private vehicles	• Develop production and distribution capability for low-sulfur diesel, so that diesel with advanced exhaust aftertreatment is a viable alternative to compressed natural gas (CNG) • Accelerate transition from two-stroke to four-stroke vehicles
Nonurban Passenger Transport	• Limit growth of short- and medium-distance air travel by identifying key intercity corridors and developing strategies to strengthen ground transport connections • Consider pricing noncommercial facility use in such a manner as to discourage noncommercial intercity vehicle-kilometers of travel (VKT) growth	
Freight Transport	• Multimodal integration • Create logistics management incentives to reduce truck vehicle-kilometers traveled	• Develop and implement fleet maintenance programs • Disseminate best practices on aerodynamic loading and vehicle operations, and incentivize their adoption (e.g. USEPA SmartWay) • Expand rail services through strategic, commodity-targeting-led investments

Source: Based on Darido 2008

CHAPTER 14
The Urban Sector

CHAPTER 14
The Urban Sector[97]

Cities have a twofold relationship with climate change. On the one hand, they are the magnets of consumption and production and their footprint accounts for the bulk of greenhouse gas emissions. On the other hand, with their high concentrations of economic activity and population, cities are also vulnerable to the impacts of climate change. Urbanization is increasing; cities around the world are projected to be home to 60 percent of the world's population by 2030, compared to 50 percent today (UNFPA 2007). This process of urbanization will inevitably be accompanied by higher incomes, innovation, and specialization and greater use of energy-intensive goods, such as cars and household appliances. The growing impact of cities will require particular consideration when planning measures to mitigate and adapt to the effects of climate change.

Greenhouse gas emissions in cities are generated primarily through transportation, energy use, and public services. Buildings use energy for lighting, heating, and cooling. Air conditioning in households is a major cause of emissions as rising temperatures result in increased energy use. This is exacerbated in cities, where temperatures are already higher than in the surrounding rural areas due to the urban heat island effect. Public services, such as power supply, wastewater disposal, sanitation, drainage and landfills, are also major contributors to GHG emissions.

The concentration of people and assets in cities increases their vulnerability to climate change. Cities are vulnerable to a range of climate-related impacts, such as flooding, storm surges, landslides, drought, saltwater intrusion, and cyclones, and also to earthquakes and other hazards, the effects of which are exacerbated by poor-quality and ill-maintained infrastructure, low-quality building stock, and the low resilience of much of the population. Coastal cities are especially endangered by rising sea levels and more intense weather phenomena, including storm surges. Other impacts include decreased water availability and adverse impact on human health due to the incidence of vector- and waterborne diseases. The poor, with their limited access to safe areas and scant livelihood opportunities, are especially vulnerable and bear the greatest burden of such impacts.

The cities are where a significant part of the battle against climate change will be won or lost. Cities can adopt various widely adopted mitigation strategies, such as improving energy efficiency,

[97] Authors in alphabetical order: Oscar E. Alvarado and Perinaz Pervez Bahda.

building codes, public transport, and capturing GHGs from wastewater treatment and solid waste disposal facilities. Furthermore, adaptation measures need to be more localized and geared to particular circumstances.

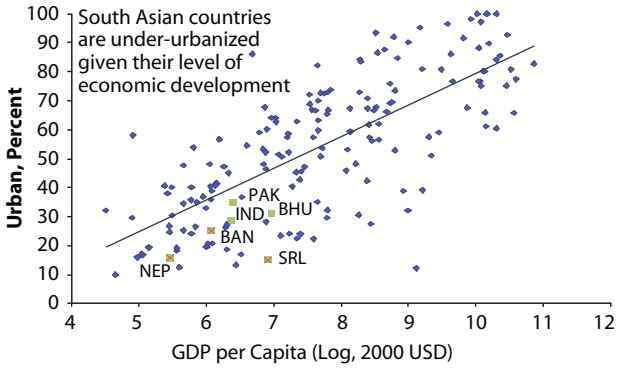
Urban Sector in South Asia

Vulnerability to Climate Change

Cities in South Asia are particularly vulnerable to climate-change impacts. This is due to a combination of nonclimatic and climatic risks. Factors such as high levels of poverty, underperformance in service delivery, infrastructure gaps, and lack of capacity increase the vulnerability of South Asian cities. Climatic risks include sea-level rise and changes in precipitation and temperature, which will affect water supply and energy availability and use, and increases in extreme events such as cyclones, floods, and droughts, impact of wind (dust, suspended particles), and so forth.

The threats are likely to grow as cities expand in a largely unplanned manner. Historically, the South Asia region has been the least urbanized region in the world (Figure 14.1). However, this trend is set to change. The annual urban growth rate is 2.53 percent, faster than that of Asia as whole (2.4 percent) and of the world (1.98 percent) (United Nations Population Division 2007). Close to 400 million people live in South Asian cities, more than the total populations of the Latin America and the Caribbean and Africa regions. The region has three of the 10 most populous countries in the world—Bangladesh, India, and Pakistan—and five of the world's megacities: Karachi, Mumbai, Delhi, Dhaka, and Kolkata. It has more than 60 urban agglomerations having populations of more than 500,000. Among South Asian countries, Pakistan has the highest urbanization rate in the region, followed by India, Bangladesh, Sri Lanka, Nepal, and Bhutan. Table 14.1 shows changes in the percentage of

Figure 14.1 Urbanization and Economic Development: South Asian Countries in World Context



Source: World Bank Calculations 2009[98]

the total population living in urban areas in South Asian countries between 1990 and 2006.

Much of this growth is fueled by rural–urban migration, and climatic stresses could induce sudden spikes in migration. Economic growth has resulted in a decrease in the proportion of households in the farm sector relative to the nonfarm sector, representing a shift in population and economic activity from rural areas to urbanized areas. For example, between 1984 and 1996, the percentage of households in the farm sector in Bangladesh decreased from 73 to 66 percent, while in the nonfarm sector it increased from 27 to 34 percent. During this period, the proportion of nonfarm households grew at a rate of about 4 percent per annum, almost triple the rate for farm households (Deshingkar and Farrington 2006). The United Nations Population Division projects that world population will grow by almost 500 million at an annual urban growth rate of 2.6 percent for the next 20 years (2007). Climatic changes in South Asia are likely to result in sudden spikes of rural–urban migration and may even cause urban unrest (Cruz et al. 2007).

[98] Data and calculations by the Urban Unit of the South Asia Region.

Table 14.1 Percentage of Total Population in Urban Areas

	1990	1995	2000	2005	2006
Afghanistan	18.3	19.7	21.3	22.9	23.3
Bangladesh	19.8	21.5	23.2	25.1	25.5
Bhutan	7.2	8.3	9.6	11.1	11.4
India	25.5	26.6	27.7	28.7	29.0
Maldives	25.8	25.6	27.5	29.6	30.1
Nepal	8.9	10.9	13.4	15.8	16.2
Pakistan	30.6	31.8	33.1	34.9	35.2
Sri Lanka	17.2	16.4	15.7	15.1	15.1

Source: UNESCAP 2007

Local governments in South Asia are struggling to cope with the rising demands and problems associated with urbanization and rapid economic growth. The region's cities lack adequate infrastructure to meet the demands of the current population and the growing influx of migrants from rural areas. The burgeoning population rapidly outpaces the provision of basic municipal services such as water, sanitation, electricity, and solid waste management. Improving living standards lead to higher demand for cars, bigger apartments, and more energy-intensive electrical goods such as televisions, refrigerators, and air conditioners. Environmental quality is rapidly deteriorating in the cities with air pollution, poor solid waste management, and polluted water resources. Some of these problems, for example air pollution and improper management of landfills, directly contribute to climate change. Other problems, such as pollution of water resources, could be minimized by adopting various climate-change adaptation strategies. Co-benefits of this nature should be further explored and adopted in combating urban-related climate-change issues.

Climate change will exacerbate the problems arising from urban poverty. Particular attention needs to be paid to climate-change impacts on the urban poor. It is well recognized that climate change will affect the poorest populations, who are usually located in high-risk urban environments and are least able to cope with changes in climate. Urban poverty in South Asian cities is significant; poor residents make up more than 50 percent of the megacities' populations. This high level of urban poverty is a major issue that needs to be addressed in urban-related climate-change agendas.

Risks Associated with Climate Change

South Asian cities will face a number of risks emanating from climate change. Three principal sources of risk—sea-level rise, changes in precipitation and temperature, and extreme events—are explored further in the ensuing paragraphs.

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Sea-level rise: Rising sea levels are predicted to negatively affect coastal infrastructure and coastal cities such as Mumbai, Kolkata, Karachi, and Chittagong. Table 14.2 shows the total urban population in South Asia and the urban population residing in the low-elevation coastal zone, less than 10 meters above sea level, in 2000. Among the South Asian countries, Bangladesh and Maldives would be the most impacted by sea-level rise in terms of percentage of land area affected by any projection of sea-level rise. More than 80 percent of the landmass of Maldives will be inundated by a one meter sea-level rise, while about a million people will be directly affected in Bangladesh by 2050. In addition, coastal areas are susceptible to increasing salinity of ground and surface water due to sea-level rise.

Changes in precipitation and temperature: Climate change is predicted to increase the variability of precipitation and raise temperatures across South Asia. This will have a range of outcomes with potential negative impacts on urban areas, including heat waves and the accompanying threat to water supplies; flooding, compounded by inadequate wastewater treatment systems and stormwater drainage facilities; and health-related issues, such as outbreaks of cholera and contamination of drinking water. Climate change will also likely bring higher frequency and intensity storms and cyclones. Particularly vulnerable are the urban poor who live in temporary shelters in typically vulnerable locations.

Climate Change and the City Governance Challenge

Facing the Institutional Challenge

Current urban management responses will be insufficient to address climate-change threats. Despite recent improvements in urban physical infrastructure, there remains a huge gap in attaining a full coverage of services. Investments have focused more on building infrastructure than on service provision. Ineffective planning has resulted in inadequate, and in some cases a total lack of, provision of services, including wastewater treatment, stormwater drainage, and collection and disposal of solid waste. Pervasive weak city and utility finances hamper further development and limit the ability of cities to solve their own problems. Investment therefore becomes heavily dependent on programs sponsored by higher levels of government.

The institutional dimension is critical when dealing with the climate-change agenda. Local

Table 14.2 Total Urban Population and Urban Population in the Low-elevation Coastal Zone in 2000

	Total Urban Population (millions)	Urban Population in Low-elevation Coastal Zone (millions)	Urban Population in Low-elevation Coastal Zone (%)
Afghanistan	4,320	0	0
Bangladesh	30,692	15,429	50
Bhutan	148	0	0
India	301,206	31,515	10
Maldives	6	6	100
Nepal	2,719	0	0
Pakistan	48,111	2,227	5
Sri Lanka	4,223	962	23

Source: SEDAC 2008

governments are often unable to work with poor communities—those most at risk. Moreover, most South Asian cities are characterized by inefficient urban planning, which has led to discriminatory land-use regulations and a limited supply of land for commercial, industrial, and residential development. Land in these cities tends to have a high price relative to household and business incomes as demand exceeds the finite supply. Many urban governments have weak capacity and are strongly influenced by central and state or provincial governments. Lack of fiscal decentralization limits the financial autonomy of cities, and their utilities are often operated by inefficient state companies, without adequate performance incentives or clear delegation of responsibilities at the city level.

Michael Foley/World Bank

There is a large overlap between the climate needs and the development needs of cities. In many cases, adaptation to climate change involves improvements in basic infrastructure, with positive outcomes for inhabitants who live in poor-quality housing; lack access to water, sanitation, and drainage facilities; and who are most likely to be affected by flooding, drought, sea-level rise, and other predicted consequences of climate change. The adaptation actions that are needed will vary by threat and location. Box 14.1 summarizes the more common elements of these.

There is also a considerable overlap between adaptation and mitigation measures in the urban context. For example, improving the energy efficiency of buildings through improved insulation, reflective glass, and efficient air conditioning will mitigate climate change by reducing GHG emissions while also rendering the urban infrastructure more adaptable to warmer climatic conditions. Mitigation and adaptation potential in solid waste management can also be explored to avert further increase in emissions and the spread of waterborne diseases related to climate change. Likewise, improving efficiency in water supply and sanitation facilities would help to both curb GHG emissions and preserve water availability and quality.

Box 14.1 Potential Strategies for Adaptation to Climate Change

Strategies to improve adaptation of cities to climate change include:

- **Drainage system:** Flooding can be mitigated by installing stormwater systems; providing proper drainage from household water, rain, and waste disposal sites; and improving solid waste and water supply.
- **Disaster risk management:** Contingency plans should be prepared to deal with natural disasters such as flooding. The building of larger water reservoirs and other facilities for sufficient storage of water in the case of drought is needed, in addition to dikes against surges of flooding and seawater.
- **Strengthening the knowledge base:** Increased knowledge of the consequences of climate change and the development of related adaptation responses in South Asian countries will render governments better able to cope with and respond to climate risks.
- **Improving energy efficiency of buildings and construction:** This measure will help reduce the heating and cooling demands of offices, dwellings, and other buildings.

Urban water supply and sanitation services, already inadequate relative to urban demand, are likely to be further jeopardized by climate change. In the region, a relatively low 84 percent of the population has access to water supply. Reduction of water wastage and leakages in urban water infrastructure, and demand management, will be some of the key strategies required to address potential threat to urban water services. In the region, approximately 35 percent of the population has access to sanitation. Wastewater treatment is generally absent, with most treatment plants not functioning. Overall, despite significant recent investments in water supply and sanitation in South Asian countries, particularly India, it is expected that the region will not attain Millennium Development Goals on these basic services. The effects of climate change will only render that shortfall more likely.

Urban infrastructure and maintenance is poor throughout the region and is essential to addressing climate threats. Inefficient water-supply systems (physical losses of more than 50 percent of the water produced are common) exacerbate the water-availability risk posed by increased droughts, and aged and inefficient pumping systems increase the demand for electricity. Flooding and the lack of wastewater treatment systems, coupled with inadequate stormwater drainage facilities, may in emergency situations result in major public health threats such as outbreaks of cholera and contamination of drinking water. Improved operational planning and maintenance of basic infrastructure are needed to ensure that services function when required.

Elements of an Urban Climate-change Approach for South Asia

An urban climate-change priority needs to be fully linked with and integrated into a larger development framework for cities and made fully coherent with the disaster-management program, with which it shares many overlapping elements. The Bank is well positioned to contribute in aspects such as policy dialogue, knowledge sharing, and capacity building. It can also contribute by initiating demonstration climate-resilient projects that can be replicated more widely. There are a number of opportunities to have ongoing and future urban projects make significant contributions to the mitigation and adaptation agendas (Box 14.2).

Concentrate on the Bank's comparative advantage. The Bank's current portfolio and near-future pipeline represent a small percentage of investment in urban infrastructure. The Bank is better positioned to contribute in aspects such as policy dialogue, knowledge sharing, and capacity building. In particular the Bank can assist cities in developing their own climate-change agendas. Also, as noted in a World Bank study on climate-change mitigation in cities (World Bank 2008b), there are a number of opportunities to make ongoing and future urban projects make significant contributions to the mitigation and adaptation agendas (Box 14.2).

Synergies between urban and climate-change priorities: The agendas for urban climate change

Box 14.2 Potential Mitigation Projects

Some mitigation projects that are in the implementation or prospective phases include the following:

- Increase of water-supply energy efficiency in Karnataka
- Composting of organic waste in Gujarat
- Urban street-lighting energy efficiency in several states in India and Pakistan
- Landfill gas recovery (CH_4) and controlled wastewater treatment in the planning stages in Bangladesh, India, and Pakistan

and city management largely coincide with and reinforce each other. For example, reducing leakage in water-supply pipes reduces wastage, which is an adaptation strategy, but also increases revenue, which is an effective city policy. In many cases, climate change does not create new infrastructure and service delivery challenges, but exacerbates current ones. Both agendas serve to reduce vulnerability by designing and building resilience to climate-related scenarios. Similarly, city development and climate-change mitigation agendas have many points in common, such as lowering pollution, increasing the efficiency of buildings, and building energy-efficient infrastructure. Given that climate-change mitigation and adaptation may not be top priorities for South Asian cities, as these cities face other pressing and more immediate challenges, the synergies between the two agendas should be highlighted.

Synergies between urban strategies and disaster risk management and reduction: Local climate-change impacts will progressively be felt through an increase in severity and frequency of disasters, such as cyclones, storms, and floods, as well as by changes in mean conditions that could alter the vulnerability of populations to hazards. Disaster risk management encompasses actions taken to reduce impacts of disasters before, during, and after they occur. Hence, one of the main entry points for engaging cities on climate change is through disaster risk management, specifically through policies and incentives that are in the pecuniary interest of cities. For example, with better land zoning and building codes as means of reducing climate change and disaster-related risks, city officials can increase value capture through increased property taxes. India is one of the few countries that have a central and various state agencies to address disaster risk management (Revi 2007).

Maximizing mitigation potential: Services such as solid-waste disposal and wastewater treatment are large generators of GHG emissions, particularly in cities with inefficient management and improper techniques. Where possible, South Asian cities could adopt mitigation strategies and access the carbon-finance market. The World Bank can play a role in knowledge and capacity building in this respect.

Institutional development: Institutional development would include assisting cities to prepare for the likely impacts of climate change. Infrastructure projects, particularly in energy, transport, and telecommunications, generally have long life spans, and it is easier to plan them in such a way as to minimize damage and destruction from extreme events.

Capacity building: The capacity of South Asian cities to put in place and implement programs related to climate change is not a priority. Lack of effective decentralization makes management of climate change a particularly large challenge. Going forward, it is important to keep in mind the following:

- States in India and provinces in Pakistan are crucial interlocutors in any climate-change effort, even in large cities.
- Larger efforts would be needed to empower cities to better face the challenges of climate-change mitigation and adaptation.
- The response to climate change represents an opportunity for cities in South Asia to hasten the pace of the decentralization agenda, thereby reaping a number of co-benefits.

Continue to promote decentralization: While most urban programs in South Asia will be funded by state or provincial and central governments, such programs should be designed in a way that places the recipient cities in the driver's seat, taking key decisions during the planning and implementation phase. Higher levels of government should have a supportive role.

The Bank's urban priorities could include the following:

- Ensure that infrastructure design includes likely impacts of climate change at an early stage and is conceived and designed taking into account predicted impacts on hydrology. Look for opportunities to include climate-change-related analytical and advisory activities.
- Share knowledge of policies and practices that have worked in the past in similar situations and across countries, and become a repository of knowledge.
- Participate in carbon finance, cap-and-trade mechanisms, and global reporting initiatives.

Michael Foley/World Bank

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 (Bangladesh, Bhutan, and the Maldives). 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 in South Asian countries. Climate projections reported in the sources consulted were derived by third parties using various 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, 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 past 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, are among the impending threats of climate change.

Observed Climate Trends

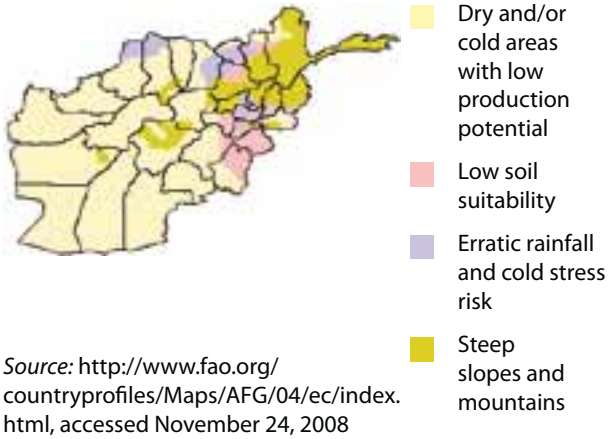
Afghanistan has experienced an increase in temperature and the frequency of hot days and nights since 1960. Average temperature increased by 0.6°C and there were 25 more hot days and nights observed than usual (UNDP 2008a).

A shortfall in precipitation of 2.0 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 cyclones and floods.

Projected Future Climate Trends

Global climate models predict that the country will experience a warming of 1.4°C to 4.0°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 0.0–6.0 percent of days by the 2090s (UNDP 2008a).



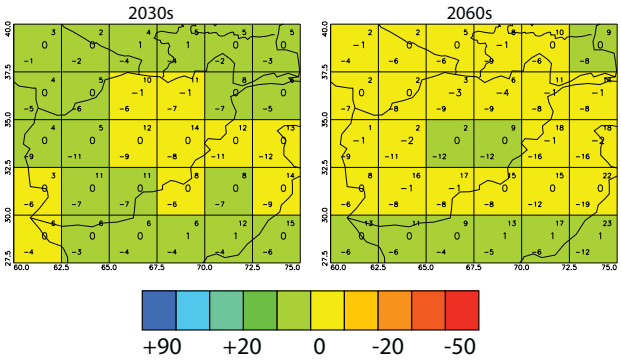
Source: http://www.fao.org/countryprofiles/Maps/AFG/04/ec/index.html, accessed November 24, 2008

Indicators

GDP: US$11.6 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 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: WRI 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***

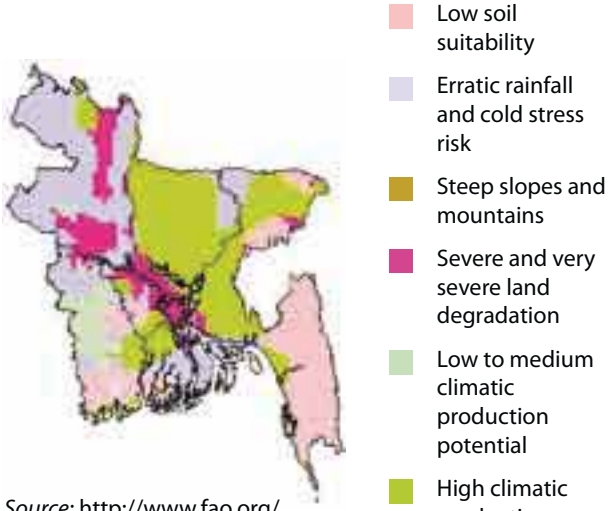
  Food insecurity, malnutrition, and possible migration and conflict

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 land is floodplain. 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 1.0°C by 2030 and by up to 2.4°C by 2100, and precipitation by 5.0 percent by 2030 and 10.0 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: WRI 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 2^0C 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 it 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 some glacier cover in recent decades has already led to the formation of supraglacial 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 to the increased risk of glacial lake outburst floods, the country has become increasingly vulnerable to floods, cyclones, landslides, and drought.

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 4.0°C, depending on the season. The highest increase is predicted for the winter months, when increases of 1.5°C to 4.0°C may occur by the 2050s (Adaptation Learning Project[99]), Both coarser and higher-resolution climate models predict an increase in precipitation in Bhutan as follows:

	Dec–Feb	Jun–Aug
2020s	–15 to +18%	+2.0 to +12.5%
2050s	–15 to +20%	+5 to +20%

Source: Adaptation Learning Project (see footnote [99])

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

[99] http://www.adaptationlearning.net/profiles/country/country.php?id=BT.

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.

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: WRI 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, 2006

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.

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

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 postmonsoon 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[100] (Government of India, Ministry of Environment and Forests 2004).

Projected Future Climate Trends

Using the Hadley Centre high-resolution model (HadRM2) for the IS92a scenario[101] 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).

[100] 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.

[101] 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: WRI 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, saline intrusion in coastal regions

- ***Public Health***

  Increased heat-related illnesses and water-borne diseases, changes in epidemiological patterns

- ***Agriculture***

  Exposure of agriculture to extreme weather events, more variable precipitation, changes in glacial cover

- ***Natural Disasters***

  Increased exposure to flood, drought, 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, 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 the 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 some 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 Maldives' GDP is based upon the tourism and fishery revenues derived from its marine resources.

With about 80 percent of the country lying less than 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.

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^{0}C and 1.1^{0}C to 1.6^{0}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 events, particularly storms generated by cyclones in other regions.

Source: GoM MEEW 2007

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.

Cyclone tracks over Maldives between 1877 and 2004

Source: Government of the Republic of Maldives, Ministry of Environment, Energy and Water (hereafter GoM MEEW) 2007

Indicators

GDP: US$1.05 billion (2007)*
GNI per capita: US$3,510 (2007)*
Population: 0.31 million (2007)*; urban 42% (2007)
Total area: 300 sq. km
Agricultural land (% total): 47

Sources: World Bank 2006; *World Bank 2008c

Sea level rise 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.	**Precipitation** 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 time frame (currently 100 years and 25 years, respectively).
Temperature • By 2025 the maximum temperature of 33.5^{0}C—currently a once-in-20-years event—will become a once-in-3-years event. • By 2100 the annual maximum temperature is projected to increase by around 1.5^{0}C.	**Extreme events** • 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 forecast to occur more frequently. Currently they are a once-in-16-years event, they are likely to become a once-in-9-years event. (UNDP Disaster Risk Profile for the Maldives 2006 in GoM MEEW 2007) • The intensity of tropical cyclones will increase by 10–20 percent (Nurse and Sem 2001 in GoM 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: WRI 2009

Key Climate Change Issues

Main Vulnerabilities

- ***Coastal and Marine Ecosystems***

  Ecosystem damage, loss of protection afforded by coral reefs

- ***Water Resources***

  Increased salinity of groundwater resources

- ***Public Health***

  Risk of loss of life due to disasters, increased incidence of vector-borne diseases

- ***Tourism***

  Reduced tourism revenues and livelihoods

- ***Disasters and Hazards***

  Physical damage from increased incidence of cyclones, 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 (GoM MEEW 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.

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 heat waves 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).

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 32% (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 2008d

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: WRI 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, 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. Geography varies across the country, shaping the great variation in the country's 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 the 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.

Observed Climate Trends

Mean annual temperature has increased by 0.35^{0}C since 1960, particularly during the months of October to December, when temperatures rose by 0.19^{0}C per decade. The annual frequency of hot days and hot nights has also increased significantly since 1960, by 20 days and 23 nights, 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 the Islamic Republic of Pakistan, Ministry of Environment 2003).

Indicators

GDP: US$143.60 billion (2007)*
Population: 162.39 million (2007)*; urban 32%* (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

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^{0}C to 3.7^{0}C by the 2060s and of 1.9^{0}C to 6^{0}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 the 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: WRI 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, 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, conflict

Low-carbon Growth Issues

- Increased emissions from energy, transport, 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 ensures 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 the country's 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.

Observed Climate Trends

The island experienced a warming of 0.48^{0}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). 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^{0}C (A2) and 1.3^{0}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).

- Low soil suitability
- Erratic rainfall and cold stress risk
- Steep slopes and mountains
- Severe and very severe land degradation
- Low to medium climatic production potential
- High climatic production potential

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 42%* (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

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: WRI 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, 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, 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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