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.

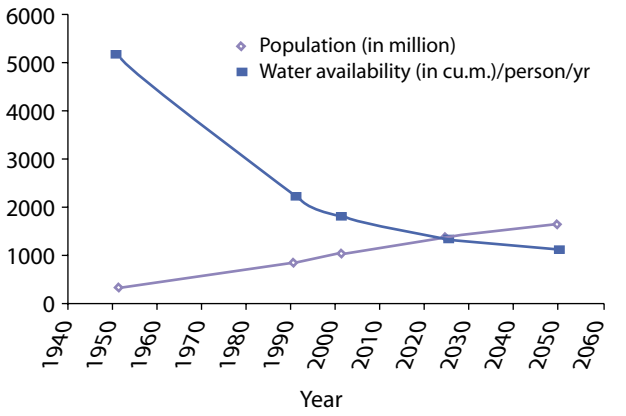
Water scarcity is another challenge. Although annual water availability appears to meet current consumption (see Figure 6.1), the data conceal

[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

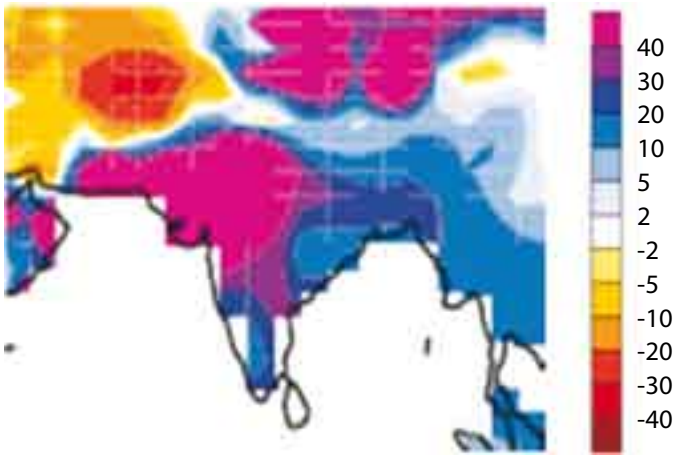
With its heavy reliance on the monsoons and snow-fed rivers, water availability in the region is highly sensitive to changes in climate. Increases in temperature are likely to result in changes in evapotranspiration, soil moisture, and infiltration. Combined with predicted changes in precipitation, this 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



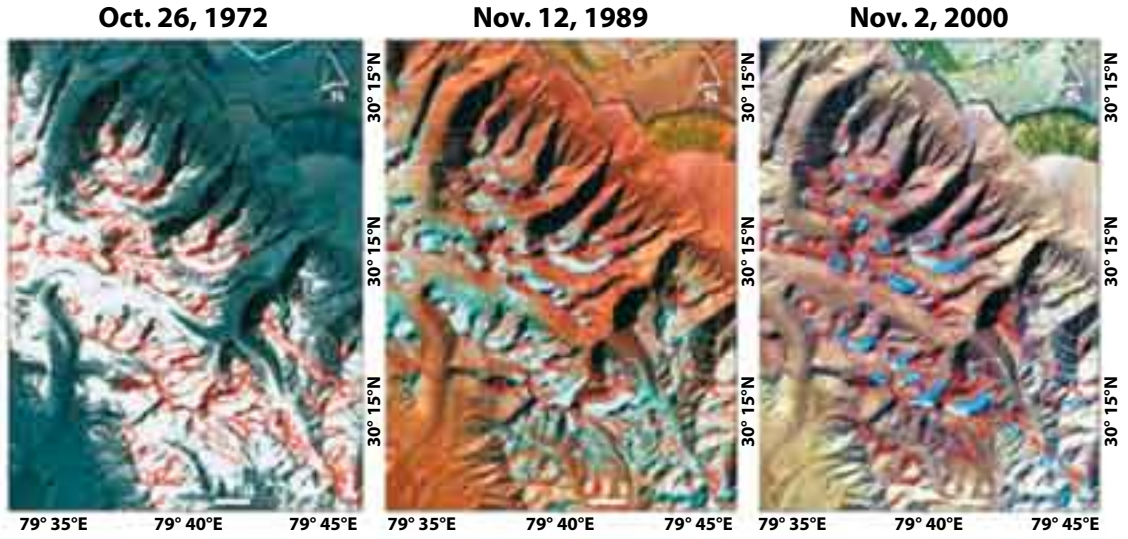
Reprinted by permission from Macmillan Publishers Ltd: *Nature* (Milly, Dunne, and Vecchia 2005)

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.