ADB

Climate Action South Asia

Steering Economies Toward Low-Carbon and Climate-Resilient Development

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The Economics of Climate Change in South Asia Adaptation and Impact Assessment

Analyses show that the cost of early action on climate change in South Asia is lower than the cost of damage brought about by climate change impacts. The region will face water shortages and agricultural food production losses, which are vital to achieving poverty reduction and other Millennium Development Goals (MDGs). South Asian countries will gain most by early inclusion of climate adaptation in their development goals. This will reduce their vulnerability and improve their resilience to impacts of climate change.

BACKGROUND

South Asia, home to about 1.5 billion people, nearly a third of whom are still living in poverty, faces a major challenge of achieving rapid economic growth to reduce poverty and attain other MDGs in an era of accentuated risks posed by global climate change. The impacts of climate change are likely to result in huge economic, social, and environmental damage to the South Asian countries, compromising their growth potential and poverty reduction efforts.

Countries in the Greater Himalayan Region, which includes Bangladesh, Bhutan, northern India, and Nepal, are facing increased frequency and magnitude of extreme weather events resulting to flooding, landslides, damage to property and infrastructure, devastation of agricultural crops, reduction of hydropower generation, and negative impact on human health. The coastal areas of Bangladesh, India, the Maldives, and Sri Lanka are at high risk from projected sea level rise, which may result in displacement of human settlements, loss of agricultural land and wetlands, saltwater intrusion, and negative impacts on tourism and fisheries.

The ADB study on Regional Economics of Climate Change in South Asia: Adaptation and Impact Assessment examined the economic costs associated with the impacts of climate change and the cost and benefits of adaptation in Bangladesh, Bhutan, India, the Maldives, Nepal, and Sri Lanka. The study covered the following sectors: agriculture, forest ecosystems, water, coastal areas (except Bhutan and Nepal), health, and energy.

Methodology

The analysis is based on a three-step modeling approach: (i) regional climate modeling, (ii) physical impact assessment, and (iii) economic assessment (integrated assessment model). The modeling was conducted under different emissions scenarios consistent with those developed by the Intergovernmental Panel on Climate Change (IPCC) as well as policy scenarios consistent with recent developments in climate change negotiations under the United Nations Framework Convention for Climate Change process. The estimates used in this study were based on how future scenarios will unfold and how societies value their future and future generations, among other things.

REGIONAL CLIMATE PROJECTIONS

A Regional Climate Model (RCM) was used over the South Asia domain at a 30-kilometer grid resolution. The A2, A1B, and B1 scenarios from the Special Report on Emissions Scenarios of the IPCC,[1] representing high, medium, and low emission futures, respectively, were adopted, covering three time horizons: 2030s, 2050s, and 2080s. Changes in these time horizons are comparisons with the base decade, 1991–2000.

[1] Intergovernmental Panel on Climate Change (IPCC). 2001. *Special Report on Emissions Scenarios.* A special report of the IPCC Working Group III. Cambridge, UK: Cambridge University Press.

Temperature. Figure 1 shows the projected temperature changes from the RCM for the different time horizons and emission scenarios. Model simulations under different scenarios indicate a significant warming trend of about 0.75°C per century in annual mean temperatures over the region. Projections indicate a steady increase in temperatures across the three time horizons, with anomalies reaching 4°C–5°C for the high emission scenarios during the 2080s.

Intergovernmental Panel on Climate Change Special Report on Emissions Scenarios (IPCC SRES)

A2: A heterogeneous world and economies; continuously increasing populations; fragmented technological change (pessimistic)

A1B: Technological change in the global energy system is not too heavily dependent on one particular energy source (median)

B1: Convergent world with reductions in resource-use intensity, and introduction of clean technologies (optimistic)

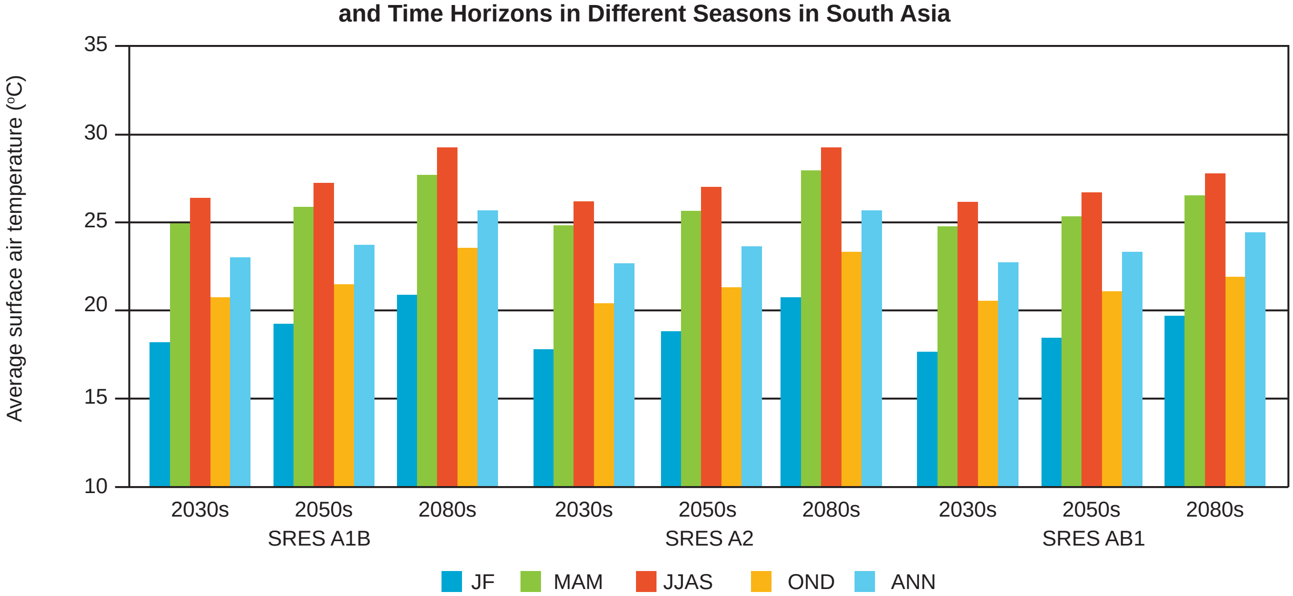
Rainfall. Spatial patterns of rainfall change (Figure 2) indicate increases in the east and northeast of the region. Increase in rainfall is seen over Bangladesh, the Maldives, and Sri Lanka. The projected precipitation increase is not consistent across time periods and becomes distinct only toward the 2080s. There is an indication of increase in daily rainfall intensity and 1-day maximum rainfall amount over many parts of the region. These changes vary across the region as well, with the changes becoming spatially contiguous only by the end of the 21st century.

RCM simulations of annual mean surface air temperatures show that the regional downscaling provides a finer spatial structure over the South Asia domain. The seasonal cycles of both temperature and precipitation agree well with the observed results. The model results have a warm bias that is seen over most of the region. Monsoon rainfall simulated by the model shows a higher mean annual number of rainy days than are observed. The wet bias in the model produces large spatial variations and the model underestimates the 1-day rainfall extremes.

The region will also experience longer periods of continuous dry days. Under the A1B scenario, model results indicate a slight increasing trend in continuous dry days across the countries up to 2080 (Figure 3).

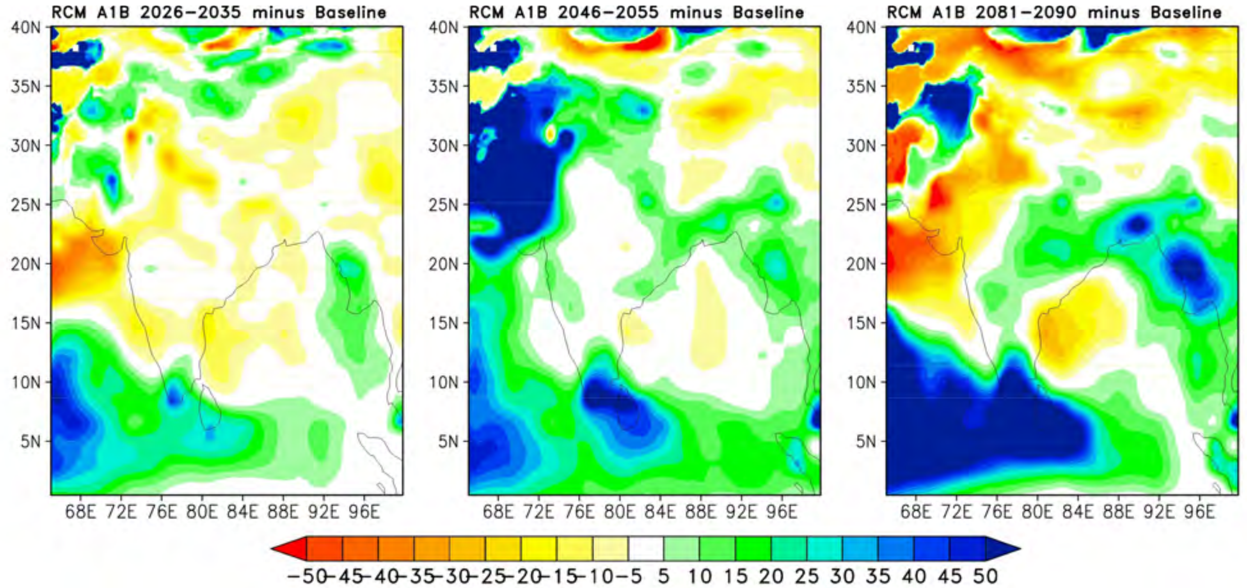
Sea level rise. Global mean sea level change results from two major processes that alter the volume of water in the global ocean: i) thermal expansion or contraction, and ii) changes in water flows from sources such as melting of glaciers and ice caps, ice sheets, and other land water reservoirs. All these processes cause geographically non-uniform sea level change.

Figure 1: Temperature Projections from the Regional Climate Model for Three Emission Scenarios and Time Horizons in Different Seasons in South Asia



A1B, A2, and B1 = projected scenarios from IPCC *Special Report on Emissions Scenarios* (SRES), ANN = annual, JF = January–February, JJAS = June–July–August–September, MAM = March–April–May, OND = October–November–December.

Figure 2: Regional Climate Model Changes in Mean Monsoon Rainfall (mm) in South Asia during Different Time Horizons under A1B Scenario



A1B = projected scenario from IPCC *Special Report on Emissions Scenarios,* mm = millimeter, RCM = regional climate model.

Based on the Geophysical Fluid Dynamics Laboratory model used in this study, the projected global sea level rise (SLR) ranges from 0.05 meters to 0.25 meters by 2050s and from 0.18 meters to 0.80 meters toward the end of the 21st century. Regional sea level data are dominated by interannual and seasonal variability and compounded by other factors, such as land subsidence and localized impacts of groundwater extraction.

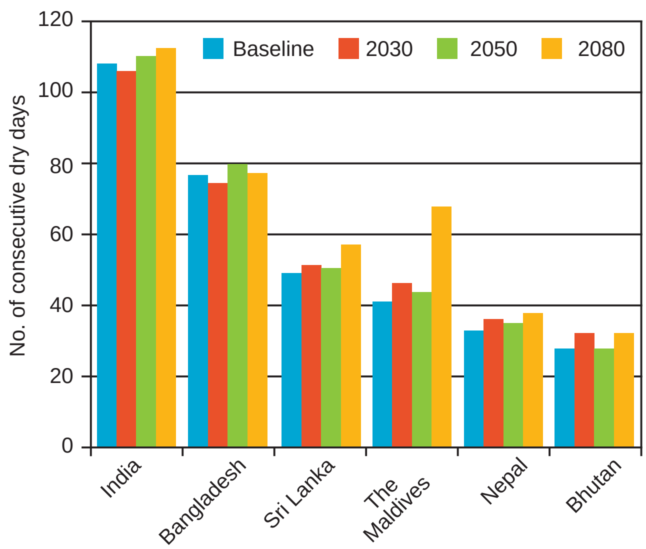
Sea level rise was examined under A2, A1B, and B1 scenarios using downscaled projections from ECHAM5.[2] Figure 4 shows the averages of SLR projections in the year 2100. The projections of SLR in South Asia (0.57 meters) are higher than the projected global (0.37 meters).

IMPACTS ON THE SECTORS

Agriculture

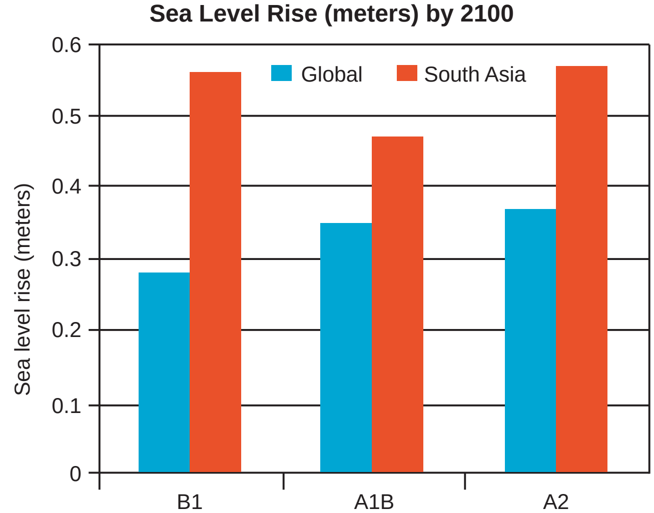
Agriculture is one of the most important sectors in South Asia. It provides stable food sources, income and livelihoods, and a social safety net for rural populations.

Figure 3: Average Number of Consecutive Dry Days in South Asian Countries



A1B = projected scenario from IPCC *Special Report on Emissions Scenarios.*

Figure 4: Projected Mean Global and South Asia Sea Level Rise (meters) by 2100



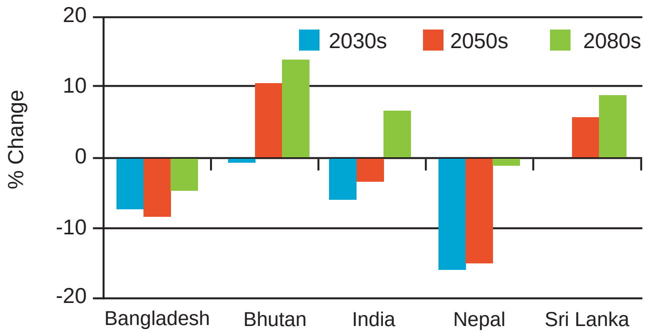
A1B, A2, and B1 = projected scenarios from IPCC *Special Report on Emissions Scenarios.*

[2] The ECHAM climate model has been developed from the ECMWF atmospheric model (therefore the first part of its name: EC) and a comprehensive parameterisation package developed at Hamburg therefore the abbreviation HAM) which allows the model to be used for climate simulations.

Higher temperatures and elevated carbon dioxide (CO_2) levels will initially cause increased photosynthesis, but beyond the physiological limits of crops, productivity will be reduced. Higher temperatures also affect precipitation, impacting the availability of water for farming. Under extreme conditions, warming will lead to severe droughts, floods, storms, and ultimately damage to crops.

Increase in both temperature and CO_2 level is projected to cause an increase in rice production in the colder climate hills and mountains of Nepal by as much as 16% by 2080s (Figure 5). Rice yield in Bhutan and India is projected to increase by the 2030s, but will begin to decline by the 2050s. Under these elevated temperature and CO_2 conditions, the tropical and subtropical regions of Bangladesh, Bhutan, India, and Sri Lanka will experience a decline in rice yield of as much as 23% by 2080s.

Figure 5: Projected Change in Rice Yield from Baseline in South Asian Countries under A1B Scenario



The Maldives is not included because it is too small for the model resolution. A1B = projected scenario from IPCC *Special Report on Emissions Scenarios.*

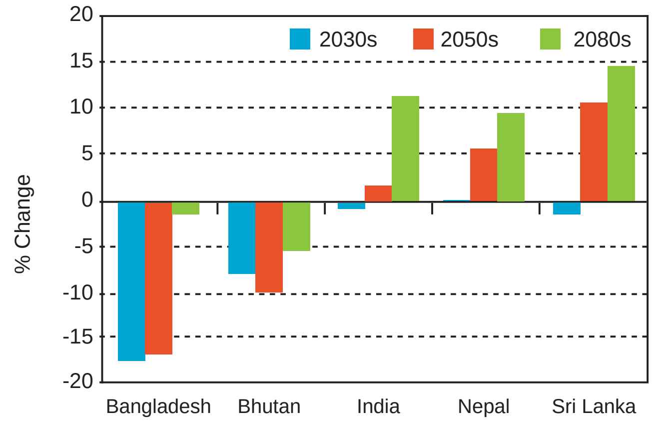
Forest Ecosystems

Forests provide raw materials and ecosystem services, such as clean air and water, temperature moderation, flood protection, and sequestration of atmospheric CO_2, which, together with other greenhouse gases, is causing global warming. Thus, maintaining and expanding forests are important adaptation strategies for climate change.

Figure 6 shows the effects of changing climate on forest ecosystems under the A1B scenario. Bhutan will absorb more carbon by the end of this century compared to the base decade partly because Bhutan has among the highest proportion of forest cover in the world (about 72.5% of its total area), low population density, and rugged mountainous landscape. In contrast, Nepal's forest remains vulnerable to further degradation. Endemic poverty of its large population and their dependence on subsistence agriculture have been the major causes of deforestation. Moreover, climate change will cause late rainy seasons with increased rain intensity, early greening of highland pastures, dry summers with more frequent forest fires, and reduced productivity of crops.

Net biome productivity (NBP) reflects the difference between the amount of CO_2 taken up from the atmosphere

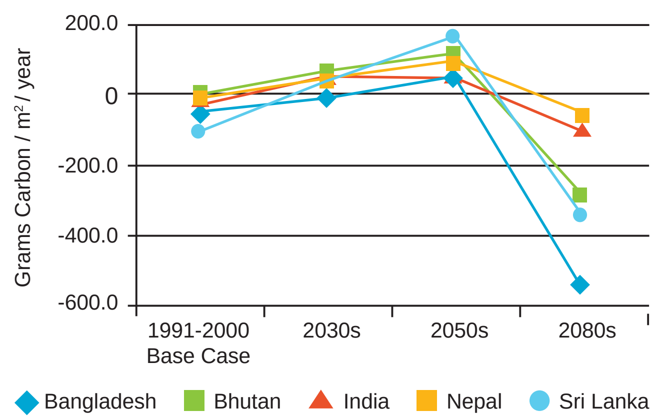
Figure 6: Projected Change (%) in Forest Carbon Pool in South Asian Countries under A1B Scenario



The projected percent changes are as compared to the 1991–2000 baseline forest ecosystem carbon level. The Maldives is not included because it is too small for the model resolution. A1B = projected scenario from IPCC *Special Report on Emissions Scenarios.*

by photosynthesis and the amount of CO_2 released by decomposition and forest fires. Up to the 2050s, NBP is projected to be positive and rising, indicating increased capture of CO_2 by photosynthesis (Figure 7). By the 2080s, all countries within the scope of the study will have a negative NBP, indicating a net release of CO_2 back to the atmosphere. This declining trend implies that forest ecosystems will be unable to compensate for rising metabolic losses due to increased temperature.

Figure 7: Projected Net Biome Productivity in South Asian Countries under A1B Scenario



m^2 = square meter.
The Maldives is not included because it is too small for the model resolution. Positive values indicate the removal (absorption or capture) of carbon dioxide from the atmosphere, while negative values show its release back to the atmosphere. A1B = projected scenario from IPCC *Special Report on Emissions Scenarios.*

Water Resources

Climate change is predicted to cause marked changes in the seasonal availability of water. This will have serious consequences on important water resources that feed the large rivers of South Asia. Due to rising temperatures, a greater proportion of the precipitation will fall as rain. Snowmelt will start earlier and winter seasons will become shorter. Reduced water availability during summer months will have serious impacts on agriculture and hydropower generation.

It is projected that river flows derived from glaciers will increase during the dry season as ice melting accelerates; this can give wrong signals to policymakers and delay climate change adaptation measures. In time, as the remaining glaciers disappear, dry season flows will be dramatically reduced. River flows will become more erratic as rainfall is immediately converted to runoff instead of being stored as ice.

Using data generated from the regional climate modeling, a geographical information system grid analysis was conducted to estimate the impacts of climate change on three key indicators, namely: (a) volume of dependable water resources, (b) average annual deficit in volume of dependable water supply, and (c) length of projected water deficits. Three time horizons representing the 2030s, 2050s, and 2080s were considered and the downscaled climate change projections for these time horizons were used in the sector impact modeling. Scenario A1B, regarded as the median scenario, was used as reference. Results are presented at the country level in Figure 8.

Water supply in Bangladesh, Bhutan, Nepal, and Sri Lanka are likely to be higher than water demand due in part to the positive effects of projected increases in rainfall. However, due to variations in the intensity and distribution of rainfall, the region overall will experience water deficits, particularly India whose water deficit will be roughly 300 billion cubic meters (m^3) by 2030 and over 400 billion m^3 by 2050 (Figure 8).

Coastal Areas

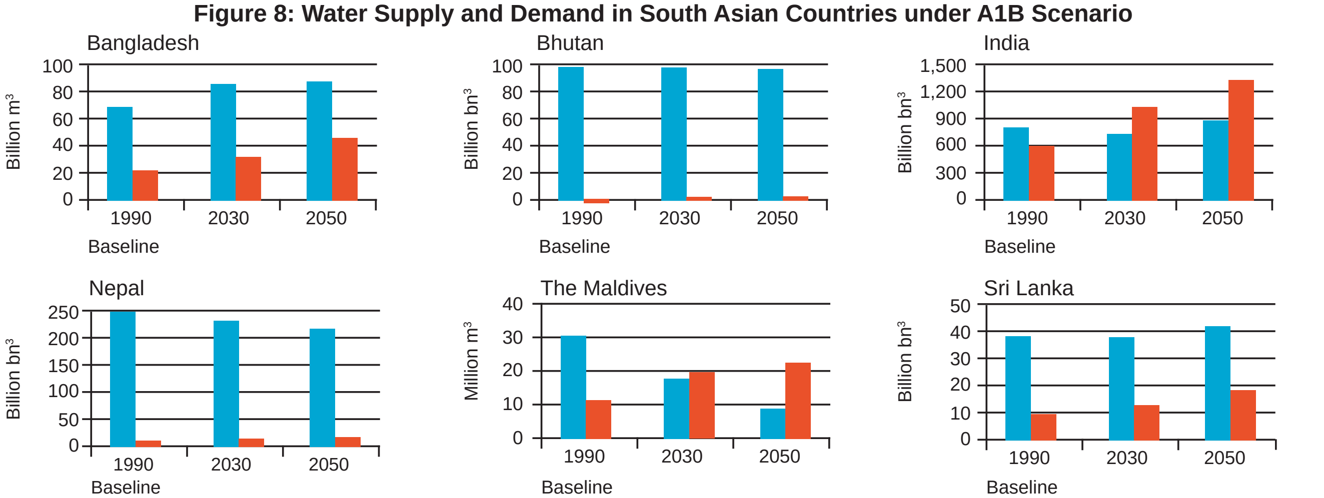
Results of the inundation modeling indicate that approximately 0.72% (20,932 square kilometers [km^2]) of drylands and 0.75% (3,694 km^2) of wetlands in the South Asian countries would be subjected to a 1-meter sea level rise (SLR). This would increase to 3.17% (91,862 km^2) when the likely effects of extreme storm surge are considered. These identified potential impacts seemingly comprise a small percentage of total land area, but about 95 million people (in 1-meter SLR) would be affected. The impacted population increases to nearly 200 million in the case of extreme storm surge for 1-meter SLR (Table 1).

Table 1: Impact of a 1-meter Sea Level Rise in Four South Asian Countries

	Inundated area at 1-meter sea level rise	Temporary inundated area due to storm surge
Total dryland area = 2,895,802 km^2		
Impacted area (km^2)	20,932	91,862
% of total dryland area	0.72	3.17
Total wetland area = 491,756 km^2		
Impacted area (km^2)	3,694	27,069
% of total dryland area	0.75	5.50
Total Population = 835,236,000		
Impacted population	95,056,125	200,112,888
% of total population	11.38	23.96

km^2 = square kilometer.
Total dryland and wetland areas do not include the Maldives. Total population is for Bangladesh, India, the Maldives, and Sri Lanka.
Source: Lehner, B., and P. Döll. 2004. Development and Validation of a Global Database of Lakes, Reservoirs and Wetlands. *Journal of Hydrology* 296. 1-4: 1-22.

Figure 8: Water Supply and Demand in South Asian Countries under A1B Scenario



Dependable water supply (includes precipitation amount available 80% of the time)   Water demand (covers irrigation, drinking, industry, and energy)

Sources:
1990 Baseline data are from United Nations. 2006. *Water: A Shared Responsibility.* The United Nations World Water Development Report 2. United Nations Educational, Scientific and Cultural Organization (UNESCO) and Berghahn Books.
Water demand data for India are from Planning Commission. 2004. *Report of the Inter Ministry Task Group on Efficient Utilisation of Water Resources.* http://planningcommission.nic.in/aboutus/taskforce/inter/inter_uwr.pdf
Water demand data for Bangladesh, Bhutan, the Maldives, and Nepal are from Reddy, M., V. Char, N. Afzal, S. Qutub, D. Basnyat, J. Karmacharya, M. Miah, S. Mukherjee, J. Nickum, K. Rahman, and K. Rasheed. 2004. *Water Demand–Supply Gaps in South Asia: Approaches to Closing Gaps.* Project on Water and Security in South Asia, implemented by the South Asia Program, School of Advanced International Studies, Johns Hopkins University, Washington, DC.

Health

Climate and anomalous weather events are expected to cause a general increase in the number of cases of both vector- and water-borne diseases. The modeling results suggest that the mortality rate for the region caused by dengue, malaria, and diarrhea would increase over time as a consequence of climate change (Table 2).

Table 2: Projected Morbidity and Mortality for Vector- and Water–Borne Diseases in South Asia

Vector- and Water–Borne Diseases	No. of cases by 2030	No. of cases by 2050	No. of cases by 2080
Dengue			
Morbidity	79,265	121,157	211,644
Mortality	665	969	1,574
Malaria			
Morbidity	2,719,519	1,921,305	1,377,479
Mortality	5,419	10,477	16,451
Diarrhea			
Morbidity	20,784,937	28,130,798	41,721,929
Mortality	3,686	5,972	9,573
TOTAL Morbidity	**23,583,721**	**30,173,260**	**43,311,052**
TOTAL Mortality	**9,770**	**17,418**	**27,598**

Energy

Climate change will affect power supply and demand within the region. The demand for energy is expected to grow fourfold by 2030 to support economic growth, as well as to provide electricity to 400 million people who still lack access to energy.[3]

Energy supply in the region is constrained by volatile world oil prices and aggravated by droughts (affecting hydropower generation), high temperatures (affecting demand for cooling systems), insufficient installed capacity, and inefficiencies of power plants.

However, climate change effects on energy supply and demand will depend on climatic variables as well as other factors like patterns of economic growth, land use, population growth and distribution, technological change, and social and cultural trends in each country. Table 3 summarizes the highest demand and supply gap in South Asia and percentage values with respect to the baseline power demand.

Table 3: Projected Demand–Supply Gap Based on Baseline Power Demand in South Asian Countries

Country	2030 Demand–Supply Gap		2050 Demand–Supply Gap	
	In Terawatt-Hours	As % of the Baseline Demand	In Terawatt-Hours	As % of the Baseline Demand
Bangladesh	4.3	1.6	13.1	6.2
Bhutan	0.7	20.0	2.2	27.0
India	147.5	7.8	370.6	7.0
The Maldives	0.03	2.7	0.13	4.3
Nepal	1.6	25.8	4.2	31.8
Sri Lanka	1.3	5.6	1.9	4.2

ECONOMIC ASSESSMENT

The economic assessment focuses on policy-based (action-based) scenarios, unlike the sector modeling in which the scenarios are climate-based.

Based on new sector assessments and existing literature, an integrated assessment model was used to (i) analyze long-term economic impacts of climate change and (ii) estimate the magnitude of funding required in South Asia to respond to climate change.

Integrated Assessment Scenarios

Business–as–Usual (BAU) Scenario: Assumes that there is no adaptation effort/investment beyond the current level. (Although a "no action" assumption may be unrealistic, the scenario creates a benchmark against which scenarios with action are evaluated.) It is consistent with a high emission scenario (between A2 and A1FI).

Copenhagen–Cancun (C–C) Scenario: Assumes decoupling of greenhouse gas emissions from BAU economic growth and imposes the implementation of Copenhagen Accord pledges (toward 2020) with a long-term vision that is in line with Cancun Agreements, aimed at keeping the global mean temperature below 2°C.

Economic Damage and Losses

Economic findings suggest that the total climate change cost in South Asia will increase over time and will be prohibitively high in the long term. Without global deviation from fossil fuel-intensive path, South Asia could

[3] World Bank. 2009. *South Asia: Shared Views on Development and Climate Change.* World Bank South Asia Region Sustainable Development Department and the International Bank for Reconstruction and Development. Washington DC.

lose an equivalent of 1.8% of its annual gross domestic product (GDP) by 2050, increasing to 8.8% by 2100 on the average (Figure 9).

Figure 10 shows country-specific climate change damage in 2100 under the business–as–usual (BAU) and the Copenhagen–Cancun (C–C) scenarios, based on the average simulation outcomes. Under the C–C scenario, the total economic costs of climate change will be kept to manageable levels across South Asia. The differences between the results from the two scenarios indicate the benefits in the six countries from the global shift toward the C–C scenario.

Adaptation Costs

Probabilistic cost of climate change provides useful information for adaptation. The incremental cost of adapting to future climates was estimated for three different temperature and SLR scenarios. The study took into account the investment in building adaptive capacity in anticipation of future climate change as well as climate proofing measures in key sectors toward climate-resilient development.

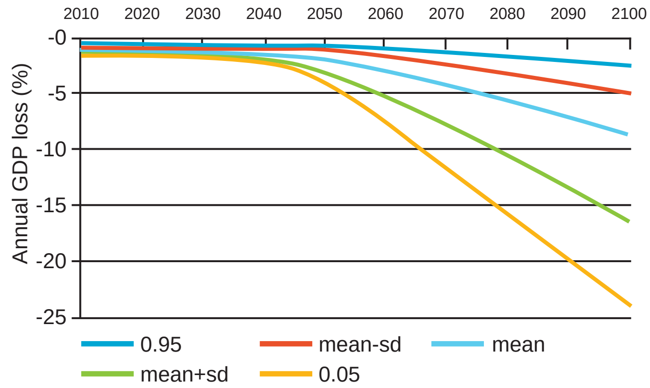
Adaptation need depends on global mitigation progress. Table 4 illustrates that to avoid increasing damage from climate change impact under a BAU scenario (e.g., adapting to 4.5°C temperature rise and to 0.7 meters SLR) toward 2100, adaptation investment of 0.86% of GDP on average is required per annum between now and 2050.

For South Asia to be fully prepared for the worst case scenario, the region would require funding with the magnitude of 1.3% of GDP on average per annum between now and 2050. This could rise up to 2.3% of GDP per annum, taking into account climate uncertainties.

Adaptation Options

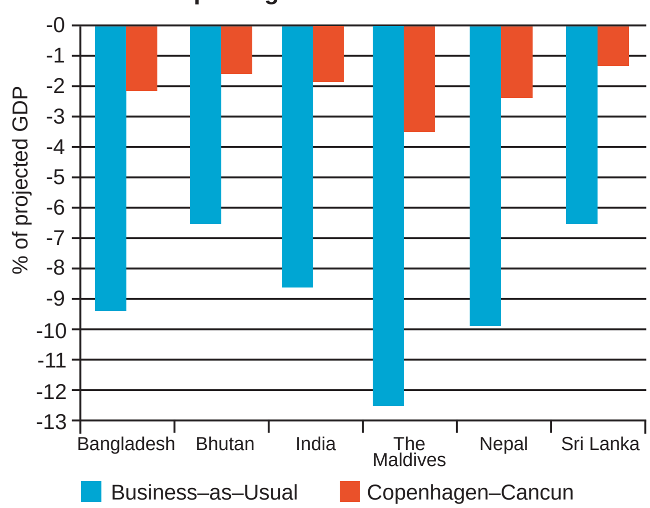
It is more challenging to adapt to climate impacts under a BAU scenario than to adapt to lower emission scenarios. Climate change adaptation is a risk management challenge involving many uncertainties. A flexible learning approach to crafting policies for climate adaptation is useful when dealing with uncertainty, starting with measures that will not be regretted.

Figure 9: Total Economic Cost of Climate Change in South Asia under Business–as–Usual Scenario



GDP = gross domestic product, sd = standard deviation.

Figure 10: Mean Economic Cost of Climate Change (as % GDP) in South Asian Countries under Business–as–Usual and Copenhagen–Cancun Scenarios in 2100



GDP = gross domestic product.
The business-as-usual (BAU) condition assumes no adaptation effort or investment beyond the current level. Although a "no action" assumption may be unrealistic, the scenario creates a benchmark against which scenarios with action are evaluated. The BAU scenario is consistent with a high-emission scenario (between A2 and A1F1).
The Copenhagen–Cancun condition assumes decoupling of greenhouse gas emissions from BAU economic growth, and imposes the implementation of Copenhagen Accord pledges (toward 2020) with a long-term vision in line with Cancun Agreements, aimed at keeping the global mean temperature below 2°C.

Table 4: Annual Average Adaptation Cost during 2010-2050 for South Asia

Policy Scenario	Adaptation Target	$ billion		GDP (%)	
		Annual average cost	Range	Annual average cost	Range
BAU_1	2100 worst case (6.9°C, 1.1m SLR)	110.9	51.2-198.0	1.32	0.64-2.29
BAU_2	2100 (4.5°C, 0.70m SLR)	72.6	33.1-127.8	0.86	0.42-1.46
BAU_3	2050 (2.5°C, 0.30m SLR)	40.2	18.3-71.5	0.48	0.23-0.81
$C–C_1$	2100 (2.5°C, 0.55m SLR)	40.6	18.8-71.4	0.48	0.24-0.82
$C–C_2$	2050 (1.9°C, 0.30m SLR)	31.0	14.2-54.5	0.36	0.18-0.62

BAU = Business–as–Usual scenario, C–C = Copenhagen-–Cancun scenario, GDP = gross domestic product, m = meters, SLR = sea level rise.

The following are some of the climate adaptation approaches and measures that can benefit from policy support:

Agriculture Sector

- Shift to crop cultivation systems with better water and nutrient-use efficiencies
- Modify cropping calendars to adjust to climate change, including improved seasonal weather forecasts
- Prioritize measures that farmers can practice now, combined with a long-term strategy to adapt to potential extreme weather patterns

Water Resources Sector

- Combine water-use productivity and efficiency measures with new supply measures
- Emphasize agricultural water productivity, as it makes up a disproportionately large fraction of present and future water demand
- Build more storage reservoirs to offset increased variability in river flows
- Combine engineering solutions with disaster risk reduction, such as early warning systems, as adaptation measures for extreme weather events

Forest Sector

- Establish forest plantations using tree species adapted to a wide range of climate conditions (including pests and diseases) and suitable for multiple use
- Invest in genetic mapping of climatically adaptable forest tree species
- Foster economic resiliency among forest-dependent populations
- Combine community forestry programs with reducing emissions from deforestation and forest degradation initiatives to access financing

Coastal Sector

- Mainstream climate change adaptation in integrated coastal zone management
- Avoid short-term solutions that may result in long-term problems, e.g., improper building of coastal dikes
- Restore mangrove systems to protect coastlines
- Establish national and international fishery management institutions for managing climate change impacts, including the breeding of high temperature-tolerant fish species

Health Sector

- Initiate surveillance measures for climate-sensitive diseases in vulnerable or high-risk areas
- Set up databases on climate-sensitive vector- and water-borne diseases and their geographic distribution
- Prioritize research and education on climate-related diseases; train health professionals and educate communities
- Set up early warning systems for disease outbreaks

Energy Sector

- Invest in demand-side management and reduce transmission and distribution losses
- Augment and diversify power generation capacity, with emphasis on renewable energy sources
- Protect generation, transmission, and distribution facilities from climate-related disruptions, e.g., extreme weather

CONCLUSION

This study suggests that, without global deviation from a fossil fuel-intensive path, South Asia could lose a sizeable portion of its GDP, 1.8% by 2050 and 8.8% by 2100. Countries will be able to avoid some economic damage to their GDP if the Copenhagen–Cancun scenario materializes, although not all because the impact of climate change is already evident. Under the Copenhagen–Cancun scenario, Bangladesh would regain 7.3% of annual GDP equivalent by 2100, Bhutan 4.8%, India 6.8%, the Maldives 9.1%, Nepal 7.5%, and Sri Lanka 5.1%. There is no time for delay in global mitigation efforts—underachieving means adapting to increasing climatic challenges and catastrophic risks in South Asia.

Climate change response policies (both adaptation and mitigation) are most effective when they are fully integrated within an overall national development strategy. Further, it is evident that region wide actions are urgently needed in South Asia. Such actions will require greater cooperation and coordination within and among the countries in the region to promote capacity building, research and development, and best practice sharing. Only through early action can South Asian countries be fully prepared against severe climate change impacts.

All photos credit to ADB.

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