Chapter 2
Climate Change in South Asia

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Abstract South Asia, is home to over one fifth of the world's population and is known to be the most disaster prone region in the world. The high rates of population growth, and natural resource degradation, with continuing high rates of poverty and food insecurity make South Asia one of the most vulnerable regions to the impacts of climate change. In general, past and present climate trends and variability in South Asia can be characterized by increasing air temperatures and there is an increasing trend in the intensity and frequency of extreme events in South Asia over the last century. Temperature projections for South Asia for the twenty-first century suggest a significant acceleration of warming over that observed in the twentieth century. Recent modelling experiments indicate that the warming would be significant in Himalayan Highlands including the Tibetan Plateau and arid regions of Asia. An increase in occurrence of extreme weather events including heat wave and intense precipitation events is projected in South

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Asia, along with an increase in the interannual variability of daily precipitation in the Asian summer monsoon. The projected impacts of climate change in South Asia will vary across sectors, locations and populations. Temperature rise will negatively impact crop yields in tropical parts of South Asia where these crops are already being grown close to their temperature tolerance threshold. While direct impacts are associated with rise in temperatures, indirect impacts due to water availability and changing soil moisture status and pest and disease incidence are likely to be felt. The most significant impacts are likely to be borne by small-holder rainfed farmers who constitute the majority of farmers in this region and possess low financial and technical capacity to adapt to climate variability and change. The projected impacts of climate change in different parts of South Asia are described. The coping capacity of the rural poor, especially in the marginal areas, is low and there is a need to mainstream the good practices for adaptation to climate change into sustainable development planning in the region. Improved understanding of the climate change impacts, vulnerability and the adaptation practices to cope with climate change could help this process.

Keywords Indian sub-continent • Mangroves • El-Niño • ENSO • Rainfall variability • Productivity • Fisheries • Sea level rise

Abbreviations

ENSO	El Niño Southern Oscillation
FAR	Fourth Assessment Report
GDP	Gross Domestic Product
GHG	Greenhouse gas
GLOF	Glacial Lake Outburst Flood
HDR	Human Development Report
NAO	North Atlantic Oscillation
UNEP	United Nations Environment Program
WMO	World Meteorological Organization

2.1 Introduction

South Asia, comprising of eight countries i.e., Afghanistan, Bangladesh, Bhutan, India, the Maldives, Nepal, Pakistan and Sri Lanka, is home to over one fifth of the world's population (Table 2.1) and is the most densely populated geographical region in the world. South Asia is known to be the most disaster prone region in the world (UNEP, United Nations Environment Programme 2003). Although agricultural sector in South Asia is continuing to grow, it is declining in relative importance, both in terms of its contribution to GDP (Table 2.1) and its share of the labour force. Urbanization is increasing, and farm households are diversifying their sources of income beyond agriculture. This relative decline of agriculture is inevitable in countries that experience

Table 2.1 Statistics of various South Asian countries for 2008

Country	Area (km^2)	Population (millions)	Arable land (%)	GDP growth rate (%)	Agric. contribution to GDP (%)
Afghanistan	652,230	28.40	12.13	3.4	31.0
Bangladesh	143,998	156.05	55.39	4.9	19.1
Bhutan	38,394	0.69	2.3	21.4	22.3
India	3,287,263	1,166.08	48.83	7.4	17.6
The Maldives	298	0.40	13.33	5.7	7.0
Nepal	147,181	28.57	16.07	4.7	32.5
Pakistan	796,095	176.24	24.44	2.7	20.4
Sri Lanka	65,610	21.32	13.96	6.0	13.4

economic growth, which has been widespread in the region. Nevertheless, a significant percentage of the economically active population is still involved in agriculture in South Asia, and agricultural employment is especially important for the livelihoods of the poor. South Asia is also home to a majority of the world's poor. According to FAO (2009), 1.02 billion people are undernourished worldwide in 2009. About 456 million people in South Asia are estimated to be undernourished.

In the recent past, climate change emerged as the single most pressing issue facing society on a global basis, with serious implications for the food security of billions of people in the developing countries. The inter-annual, monthly and daily distribution of climate variables (e.g., temperature, radiation, precipitation, water vapor pressure in the air and wind speed) affects a number of physical, chemical and biological processes that drive the productivity of agricultural, forestry and fisheries systems (Easterling et al. 2007). The high rates of population growth, and natural resource degradation, with continuing high rates of poverty and food insecurity make South Asia one of the most vulnerable regions to the impact of climate change. Land use, land degradation, urbanization and pollution, affect the ecosystems in this region directly and indirectly through their effects on climate. These drivers can operate either independently or in association with one another (Lepers et al. 2005). Complex feedbacks and interactions occur on all scales from local to global. Cassman et al. (2003) emphasize that climate change will add to the dual challenge of meeting food (cereal) demand while at the same time protecting natural resources and improving environmental quality in these regions. In the long run, climate change impacts, such as changes in temperature, shifts in growing seasons, storms, floods, droughts, and changed rainfall patterns, risk the livelihood of drylands populations. Therefore, adaptation to the adverse effects of climate change through sustainable land management is a crucial, though simultaneously challenging, task.

2.2 Climate Change

The climate system is a complex, interactive system consisting of the atmosphere, land surface, snow and ice, oceans and other bodies of water, and living things. The Intergovernmental Panel on Climate Change (IPCC) was established in 1988, by the World Meteorological Organization (WMO) and the United Nations Environment Program (UNEP), to assess scientific information on climate change, as well as its environmental and socioeconomic impacts, and to formulate response strategies. Climate change is defined by the IPCC as any change in climate over time, whether due to natural variability or as a result of human activity (IPCC 2007). Evidence from observations of the climate system has led to the conclusion that human activities are contributing to a warming of the earth's atmosphere. Human activities – primarily burning of fossil fuels and changes in land cover – are modifying the concentration of atmospheric constituents or properties of the Earth's surface that absorb or scatter radiant energy. In particular, increases in the concentrations of greenhouse gases (GHGs) and aerosols are strongly implicated as contributors to climatic changes observed during the twentieth century and are expected to contribute to further changes in climate in the twenty-first century and beyond. In the 1950s, the greenhouse gases of concern remained CO_2 and H_2O, the same two identified by Tyndall (1861) a century earlier. It was not until the 1970s that other greenhouse gases – CH_4, N_2O and CFCs – were widely recognized as important anthropogenic greenhouse gases (Ramanathan 1975; Wang et al. 1976; IPCC 2007). By the 1970s, the importance of aerosol-cloud effects in reflecting sunlight was known (Twomey 1977), and atmospheric aerosols (suspended small particles) were being proposed as climate-forcing constituents. The amount of carbon dioxide in the atmosphere has increased by about 35% in the industrial era, and this increase is known to be due to human activities, primarily the combustion of fossil fuels and removal of forests. These changes in atmospheric composition are likely to alter temperatures, precipitation patterns, sea level, extreme events, and other aspects of climate on which the natural environment and human systems depend.

As climate science and the Earth's climate have continued to evolve over recent decades, increasing evidence of anthropogenic influences on climate change has been found. Correspondingly, the IPCC has made increasingly more definitive statements about human impacts on climate. IPCC released its Fourth Assessment Report (FAR) in 2007 that focused on observed climate change and the potential impacts of future climate change. The sections below on observed and future climate change borrow heavily from the information provided in FAR.

2.2.1 Observed Climate Change

At the time of the Third Assessment Report of IPCC, scientists could say that the abundances of all the well-mixed greenhouse gases during the 1990s were greater than at any time during the last half-million years (Petit et al. 1999), and this record now extends back nearly 1 million years (IPCC 2007). In 2005, the concentration of carbon dioxide exceeded the natural range that has existed over 650,000 years. Evidence from observations of the climate system show an increase of $0.74 \pm 0.18°C$ in global average surface temperature during the 100 year period from 1906 to 2005 and an even greater warming trend over the 50 year period from 1956 to 2005 than over the entire 100 year period i.e., 0.13°C ± 0.03°C vs. 0.07°C ± 0.02°C per decade (IPCC 2007). Eleven of the 12 year period between 1995 and 2006 are among the 12 warmest years since the instrumental record of global surface temperature was started in 1850 (IPCC 2007). Land regions have warmed at a faster rate than the oceans. Warming has occurred in both land and ocean domains, and in both sea surface temperature (SST) and nighttime marine air temperature over the oceans. However, for the globe as a whole, surface air temperatures over land have risen at about double the ocean rate after 1979 (more than 0.27°C per decade vs 0.13°C per decade).

The following information on the observed climate change in South Asia was summarized from the report of the Working Group II chapter on Asia (Chapter 10 – Cruz et al. 2007) of IPCC. In general, past and present climate trends and variability in Asia can be characterized by increasing air temperatures which are more pronounced during winter than in summer. During recent decades, the observed increases in some parts of Asia have ranged between less than 1–3°C per century. Across all of Asia, interseasonal, interannual and spatial variability in rainfall trend has been observed during the past few decades. Decreasing trends in annual mean rainfall have been observed in the coastal belts and arid plains of Pakistan and parts of North-East India with increasing trends in Bangladesh. Table 2.2 provides a detailed list on observed characteristics in surface air temperature and rainfall for some of the countries in South Asia.

As for extreme climatic events, there has been new evidence on recent trends, particularly on the increasing tendency in the intensity and frequency of these events in South Asia over the last century. There have been significantly longer

Table 2.2 Summary of key observed past and present climate trends and variability in some countries in South Asia (Cruz et al. 2007)

Country	Change in temperature	Change in precipitation
Bangladesh	Increasing trend of about 1°C in May and 0.5°C in November from 1985 to 1998	Decadal rain anomalies above long term averages since 1960s
India	0.68°C increase per century with increasing trends in annual mean temperature and warming more pronounced during post monsoon and winter	Increase in extreme rains in north-west during summer monsoon in recent decades and lower number of rainy days along east coast
Nepal	0.09°C increase per year in Himalayas and 0.04°C in Terai region with more in winter	No distinct long-term trends in precipitation records for 1948–1994
Pakistan	0.6–1.0°C increase in mean temperature in coastal areas since early 1900s	10–15% decrease in coastal belt and hyper arid plains and increase in summer and winter precipitation over the last 40 years in northern Pakistan
Sri Lanka	0.016°C increase per year between 1961 to 90 over entire country and 2°C increase per year in central highlands	An increase trend in February and decrease trend in June

heat waves in many countries of South Asia with several cases of severe heat waves. The AR4 report noted that, in general, the frequency of more intense rainfall events in many parts of Asia has increased, causing severe floods, landslides, and debris/mud flows. It is interesting that at the same time, the number of rainy days and total annual amount of precipitation has decreased. Therefore, the total amount rainfall has decreased but the rain has been concentrated in few days. Analysis of rainfall data for India highlights the increase in the frequency of severe rainstorms over the last 50 years. The number of storms with more than 100 mm rainfall in a day is reported to have increased by 10% per decade (UNEP, United Nations Environment Programme 2007).

An example of this can be demonstrated by the extreme rainfall event which occurred in Mumbai, India on 26 and 27 July 2005. In a matter of 18 h, 944 mm of rain was recorded which was the highest rainfall ever recorded in the last 100 years in India. Mumbai and adjacent areas of Maharashtra experienced one of their worst floods in history (Government of Maharashtra 2005).

In many parts of South Asia, there have been an increasing frequency and intensity of droughts. The linear trends of rainfall decreases for 1900–2005 were 7.5% in South Asia (significant at <1%). Droughts have become more common, especially in the tropics and subtropics, since the 1970s (IPCC 2007). Observed marked increases in drought in the past three decades arise from more intense and longer droughts over wider areas, as a critical threshold for delineating drought is exceeded over increasingly widespread areas. Decreased land precipitation and increased temperatures that enhance evapotranspiration and drying are important factors that have contributed to more regions experiencing droughts, as measured by the Palmer Drought Severity Index. Also, there has been a noted decrease in the number of cyclones originating from the Bay of Bengal and Arabian Sea since 1970 but the intensity of these storms has increased and the damage caused by intense cyclones has risen significantly in India and the Tibetan Plateau. Table 2.3 details a summary of observed changes in extreme events and severe climate anomalies in South Asia.

During the twentieth century, the changes in temperature and precipitation described above caused important changes in hydrology over large regions. One change was a decline in spring snow cover. Less snow generally translates to lower reservoir levels. The earlier onset of spring snowmelt exacerbates this problem. Snowmelt started 2–3 weeks earlier in 2000 than it did in 1948 (Stewart et al. 2004). Particularly worrisome is the reduction in the mass balance of the glaciers and this has serious implications for the availability of water for over 500 million people in South Asia.

Another manifestation of changes in the climate system is a warming in the world's oceans. The global ocean temperature rose by 0.10°C from the surface to 700 m depth from 1961 to 2003 (IPCC 2007). Warming causes seawater to expand and thus contributes to sea level rise. This factor, referred to as thermal expansion, has contributed 1.6 ± 0.5 mm per year to global average sea level over the last decade (1993–2003). Other factors contributing to sea level rise over the last decade include a decline in mountain glaciers and ice caps (0.77 ± 0.22 mm per year) (IPCC 2007). In the coastal areas of Asia, the current rate of sea-level rise is reported to be between 1 and 3 mm/year which is slightly greater than the global

Table 2.3 Summary of observed changes in extreme events and severe climate anomalies in South Asia (Cruz et al. 2007)

Climatic event	Observed change
Heat waves	Frequency of hot days and multiple-day heat wave has increased in past century in India with an increase in deaths due to heat stress in recent years.
Intense rains and floods	Serious and recurrent floods in Bangladesh, Nepal and north-east states of India during 2002, 2003 and 2004; floods in Surat, Barmer and in Srinagar of India during summer monsoon season of 2006; 17 May 2003 floods in southern province of Sri Lanka were triggered by 730 mm rain.
Droughts	50% of droughts associated with El Niño; consecutive droughts in 1999 and 2000 in Pakistan and Northwest India led to sharp decline in water tables; consecutive droughts between 2000 and 2002 caused crop failures, mass starvation and affected ~11 million people in Orissa, India; droughts in Northeast India during summer monsoon of 2006.
Cyclones/typhoons	Frequency of monsoon depressions and cyclones formation in Bay of Bengal and Arabian Sea on the decline since 1970 but intensity is increasing causing severe floods in terms of damages to life and property.

average. The rate of sea-level rise of 3.1 mm/year has been observed over the past decade compared to 1.7–2.4 mm/year over the twentieth century which suggests that the rate of sea level rise has accelerated relative to the long-term average.

Chapter 10 of the IPCC Working Group II report also summarized the impacts of observed changes in climate. For agriculture, the report noted that the production of rice, maize and wheat over recent decades has declined in many parts of Asia due to increasing water stress partly due to increasing temperature, increasing frequency of El Niño’s and a lower number of rainy days. The chapter summarizes a study by the International Rice Research Institute which observed a 10% decrease in rice yield for every 1°C increase in growing-season minimum temperature (Peng et al. 2004). For water resources, there is concern about melting glaciers, since they account for over 10% of freshwater supplies the drier parts of Asia. There have been observations of Asian glaciers melting faster than in the past, especially in Central Asia, Western Mongolia and North-West China. However, studies in northern Pakistan indicate that glaciers in the Indus Valley region may be expanding, due to increases in winter precipitation over western Himalayas during the past 40 years. In India, Pakistan, Nepal and Bangladesh, water shortages have been attributed to rapid urban growth, industrialization, population growth and inefficient water use, which are exacerbated by a changing climate and its negative impacts on water demand, supply and quality.

The coastlines of South Asia are highly prone to cyclones and the combination of extreme climatic and non climatic events have caused coastal flooding, resulting in substantial economic losses and fatalities. In the major river deltas of the region, wetlands have been significantly altered in recent years due to large scale sedimentation, land-use conversion, logging and human settlement. Also, salt water is reported to have penetrated 100 km or more inland along tributary channels of the Bay of Bengal during the dry season. Along the South Asian coastlines, a large portion of the mangroves, which help prevent salt-water intrusion have been reportedly lost during the last 50 years largely due to human activities.

In the coastal areas of Asia, the current rate of sea-level rise is reported to be between 1 and 3 mm/year which is slightly greater than the global average. The rate of sea-level rise of 3.1 mm/year has been observed over the past decade compared to 1.7–2.4 mm/year over the twentieth century which suggests that the rate of sea level rise has accelerated relative to the long-term average.

2.2.2 Future Climate Change

Looking ahead, IPCC (2007) projects increases in global mean surface air temperature (SAT) continuing over the twenty-first century, driven mainly by increases in anthropogenic greenhouse gas concentrations, with the warming proportional to the associated radiative forcing. An expert assessment based on the combination of available constraints from observations and the strength of known feedbacks simulated in the models used to produce the climate change projections indicates that the equilibrium global mean SAT warming for a doubling of atmospheric CO_2, or 'equilibrium climate sensitivity', is likely to lie in the range 2–4.5°C, with a most likely value of about 3°C (IPCC 2007). Warming in the twenty-first century is expected to be greatest over land and at the highest northern latitudes. It is very likely that heat waves will be more intense, more frequent and longer lasting in a future warmer climate.

Increasingly reliable regional climate change projections are now available due to advances in modeling and understanding of the physical processes of the climate system. IPCC (2007) projections show that drier subtropical regions are warming more than the moister tropics. Warming is likely to be above the global mean in South Asia. The temperature projections for South Asia for the twenty-first century suggest a significant acceleration of warming over that observed in the twentieth century. The increase in temperature is least rapid, similar to the global mean warming, in South-East Asia, larger over South Asia and East Asia and greatest in the continental Asia (Central, West and North Asia). Also, in general, the projected warming over Asia is higher during northern hemisphere winter than during summer for all time periods. Recent modelling experiments indicate that the warming would be significant in Himalayan Highlands including the Tibetan Plateau and arid regions of Asia.

Mean winter precipitation will very likely increase in northern Asia and the Tibetan Plateau and likely increase in West, Central, South-East and East Asia. Summer precipitation will likely increase in North, South, South-East and East Asia but decrease in West and Central Asia. Droughts associated with summer drying could result in regional vegetation die-offs (Breshears et al. 2005) and contribute to an increase in the percentage of land area experiencing drought at any one time, for example, extreme drought increasing from 1% of present-day land area to 30% by the end of the century (Burke et al. 2006).

Climate extremes encompass both extreme weather, with durations of minutes to days (the synoptic timescale), and extreme climate events with durations of months, in the case of periods of wet/stormy weather, or years, in the case of drought (McGregor et al. 2005). In all cases, the frequency of extreme events may be affected by seasonal to inter-annual fluctuations of large scale climate variations such as El Niño/Southern Oscillation (ENSO) and the North Atlantic Oscillation (NAO) (Schwierz et al. 2006).

The frequency of occurrence of climate extremes is expected to change during the next century, with increases in the frequency of heat waves and heavy precipitation events, and decreases in the frequency of frost days, as a consequence of anthropogenically-forced climate change (Easterling et al. 2000). An increase in occurrence of extreme weather events including heat wave and intense precipitation events is projected in South Asia (Lal 2003) along with an increase in the interannual variability of daily precipitation in the Asian summer monsoon (Lal et al. 2000; May 2004; Giorgi and Bi 2005). For tropical cyclones, there is a projected increase of 10–20% in the intensity of storms with an increase in sea-surface temperature of 2–4°C relative to the current temperatures in East Asia, South-East Asia and South Asia. An increase in heights of storm-surges could result from the occurrence of stronger winds, increases in sea-surface temperatures and low pressures associated with tropical cyclones resulting in an enhanced risk of coastal disasters along the coastal regions of the countries of East, South and South-East Asia.

Annual average river runoff and water availability are projected to decrease by 10–30% over some dry regions at mid-latitudes and in the dry tropics. The areas suitable for rainfed agriculture are expected to significantly decrease affecting adversely land productivity potential of the continent (Fischer et al. 2002).

2.3 Climate Change Impacts in South Asia

Projections indicate that climate variations in South Asia will be varied and heterogeneous, with some regions experiencing more intense precipitation and increased flood risks, while others encounter sparser rainfall and prolonged droughts. The impacts will vary across sectors, locations and populations. Temperature rise will negatively impact rice and wheat yields in tropical parts of South Asia where these crops are already being grown close to their temperature tolerance threshold. While direct impacts are associated with rise in temperatures, indirect impacts due to water availability and changing soil moisture status and pest and disease incidence are likely to be felt. The most significant impacts are likely to be borne by small-holder rainfed farmers who constitute the majority of farmers in this region and possess low financial and technical capacity to adapt to climate variability and change.

Following is a short summary of the expected impacts across this diverse region.

2.3.1 Impacts of Enhanced Temperatures

While plant response to elevated CO_2 is positive, recent studies confirm that the effects of elevated CO_2 on plant growth and yield will depend on photosynthetic pathway, species, growth stage and management regime, such as water and nitrogen (N) applications (Jablonski et al. 2002; Ainsworth and Long 2005). Increased temperatures may also reduce CO_2 effects indirectly, by increasing water demand. Rain-fed wheat grown at 450 ppm CO_2 demonstrated yield increases with temperature increases of up to 0.8°C, but declines with temperature increases beyond 1.5°C; additional irrigation was needed to counterbalance these negative effects (Xiao et al. 2005).

Temperature rise will negatively impact rice and wheat yields in tropical parts of South Asia where these crops are already being grown close to their temperature tolerance threshold (Kelkar and Bhadwal 2007). Kumar and Parikh (2001) show that even after accounting for farm level adaptation, a 2°C rise in mean temperature and a 7% increase in mean precipitation will reduce net revenues by 8.4% in India. Wheat yields are predicted to decline by 6–9% in sub-humid, semiarid, and arid areas with 1°C increase in temperature (Sultana and Ali 2006), while even a 0.3°C decadal rise could have a severe impact on important cash crops like cotton, mango, and sugarcane (MoE 2003). In Srilanka, half a degree temperature rise is predicted to reduce rice output by 6%, and increased dryness will adversely affect yields of key products like tea, rubber, and coconut (MENR, Ministry of Environment and Natural Resources 2000). In the hot climate of Pakistan, cereal crops are already at the margin of stress. An increase of 2.5°C in average temperature would translate into much higher ambient temperatures in the wheat planting and growing stages. Higher temperatures are likely to result in decline in yields, mainly due to the shortening of the crop life cycle especially the grain filling period. The National Communication (MoE 2003) highlighted that crops like wheat, cotton, mango, and sugarcane would be more sensitive to increase in temperatures compared to rice.

Drylands and mountain regions are likely to be more vulnerable than others (Gitay et al. 2001) and ecosystem degradation is largest in these regions (Hassan et al. 2005). Climate change is likely to cause additional inequities, as its impacts are unevenly distributed over space and time and disproportionately affect the poor (Tol 2001; Stern 2007).

2.3.2 Impacts of Precipitation Variability and Water Resources

Current vulnerabilities to climate are strongly correlated with climate variability, in particular precipitation variability. These vulnerabilities are largest in the semi-arid and arid low-income countries with large tracts of drylands, where precipitation and stream flow are concentrated over a few months, and where year-to-year variations are high (Lenton 2004). In such regions a lack of deep groundwater wells or reservoirs (i.e., storage) leads to a high level of vulnerability to climate variability, and to the climate changes that are likely to further increase climate variability in future.

Water resources are inextricably linked with climate, so the prospect of global climate change has serious implications for water resources and regional development (Riebsame et al. 1995). Tendencies of increase in intense rainfall with the potential for heavy rainfall events spread over few days are likely to impact water recharge rates and soil moisture conditions. A warmer climate, with its increased climate variability, will increase the risk of both floods and droughts (Wetherald and Manabe 2002).

South Asia is endowed with great rivers, which are the lifelines of the regional economy. The ice mass covering the Himalayan-Hindu Kush mountain range is the source of the nine largest rivers of Asia, including the Ganges, Brahmaputra, and Indus. These rivers provide water to more than half of the world's population. Many people in Asia are dependent on glacial melt water during dry season. Accelerated glacial melt questions the very perennial nature of many of the Himalayan flowing rivers. This is likely to have huge implications on those dependent on the resource affecting water availability for agricultural purposes (Kelkar and Bhadwal 2007). In Nepal and Bhutan, melting glaciers are filling glacial lakes beyond their capacities contributing to Galcial Lake Outburst Floods (GLOFs) (UNEP, United Nations Environment Programme 2007). Of 2,323 glacial lakes in Nepal, 20 have been found to be potentially dangerous with respect to GLOFs. The most significant such event occurred in 1985, when a glacial lake outburst flood caused a 10–15 m high surge of water and debris to flood down the Bhote Koshi and Dudh Koshi rivers for 90 km, destroying the Namche Small Hydro Project (Raut 2006).

Semi-arid and arid areas are particularly exposed to the impacts of climate change on freshwater. In semi-arid areas, climate change may extend the dry season of no or very low flows, which particularly affects water users unable to rely on reservoirs or deep groundwater wells (Giertz et al. 2006). Kundzewicz et al. (2007) explain that many of these areas will suffer a decrease in water resources due to climate change. The population of Maldives mainly depends on groundwater and rainwater as a source of freshwater. Both of these sources of water are vulnerable to changes in the climate and sea level rise. With the islands of the Maldives being low-lying, the rise in sea levels is likely to force saltwater into the freshwater lens. The groundwater is recharged through rainfall. Although the amount of rainfall is predicted to increase under an enhanced climatic regime, the spatial and temporal distribution in rainfall pattern is not clear (Ministry of Environment and Construction 2005).

Agricultural irrigation demand in arid and semi-arid regions of Asia is estimated to increase by at least 10% for an increase in temperature of 1°C (Fischer et al. 2002; Liu 2002). Efforts to offset declining surface water availability due to increasing precipitation variability will be hampered by the fact that groundwater recharge will decrease considerably in some already water-stressed regions, where vulnerability is often exacerbated by the rapid increase in population and water demand.

The greatest impact will continue to be felt by the poor, who have the most limited access to water resources. Rapid depletion of water resource is already a cause for concern in many countries in South Asia. About 2.5 billion people will be affected with water stress and scarcity by the year 2050 in South Asia (HDR 2006). In the drylands, farmers and pastoralists also have to contend with other extreme natural resource challenges and constraints such as poor soil fertility, pests, crop diseases, and a lack of access to inputs and improved seeds. These challenges are usually aggravated by periods of prolonged droughts and/or floods and are often particularly severe during El Nino events (Vogel 2005; Stige et al. 2006). The impact of changes in precipitation and enhanced evaporation could have profound effects in some lakes and reservoirs.

2.3.3 Impacts of Increased Frequency of Extreme Events and Natural Disasters

South Asia suffers an exceptionally high number of natural disasters. Between 1990 and 2008, more than 750 million people – 50% of the region's population – were affected by a natural disaster, leaving almost 60,000 dead and resulting in about $45 billion in damages.

Several studies showed that generally, the frequency of occurrence of more intense rainfall events in many parts of South Asia has increased, causing severe floods, landslides, and debris and mud flows, while the number of rainy days and total annual amount of precipitation has decreased (Mirza 2002; Lal 2003). Increasing frequency and intensity of droughts in many parts of South Asia are attributed largely to a rise in temperature, particularly during the summer and normally drier months, and during ENSO events (Lal 2003). An increase in the frequency of droughts and extreme rainfall events could result in a decline in tea yield, which would be the greatest in regions below 600 m (Wijeratne 1996). With the tea industry in Sri Lanka being a major source of foreign exchange and a significant source of income for laborers the impacts are likely to be grave. On an average during the period 1962–1988, Bangladesh lost about 0.5 million tonnes of rice annually as a result of floods that accounts for nearly 30% of the country's average annual food grain imports (Paul and Rashid 1993).

Short-term natural extremes, such as storms and floods, interannual and decadal climate variations, as well as large-scale circulation changes, such as the El Niño Southern Oscillation (ENSO), all have important effects on crop, pasture and forest production (Tubiello 2005). Increased climate extremes may promote plant disease and pest outbreaks (Gan 2004).

There is growing evidence that the frequency and extent of drought has increased as a result of global warming. A global analysis has shown that abrupt changes in rainfall are more likely to occur in the arid and semi-arid regions, and that this susceptibility is possibly linked to strong positive feedbacks between vegetation and climate interactions (Narisma et al. 2007). The socio-economic impacts of droughts may arise from the interaction between natural conditions and human factors, such as changes in land use and land cover, water demand and use. Excessive water withdrawals can exacerbate the impact of drought. Changes in the frequencies of extreme events will have an impact on land degradation processes such as floods and mass movements, soil erosion by both water and wind, and on soil salinization.

2.3.4 Impacts on Crop, Pasture and Forest Productivity

Agriculture is the mainstay of several economies in South Asia. It is also the largest source of employment. The sector continues to be the single largest contributor to the GDP in the region. As three-fifth of the cropped area is rainfed, the economy of South Asia hinges critically on the annual success of the monsoons (Kelkar and Bhadwal 2007). In the event of a failure, the worst affected are the landless and the poor whose sole source of income is from agriculture and its allied activities. Cruz et al. (2007) concluded that the crop yield in many countries of Asia has declined, partly due to rising temperatures and extreme weather events and that future climate change is likely to affect agriculture, risk of hunger and water resource scarcity with enhanced climate variability and more rapid melting of glaciers.

For Asia, the results of recent studies suggest that substantial decreases in cereal production potential could be likely by the end of this century as a consequence of climate change. Cruz et al. (2007) stressed, however, that regional differences in the response of wheat, maize and rice yields to projected climate change could likely be significant. Results of crop yield projections, using the HadCM2 climate model, indicate that crop yields could likely increase up to 20% in East and South-East Asia while likely decrease up to 30% in Central and South Asia even if the direct positive physiological effects of CO_2 are taken into account. In South Asia, there could be a significant decrease in non-irrigated wheat and rice yields for a temperature increase of greater than 2.5°C which could incur a loss in farm-level net revenue of between 9% and 25%. One study points out that in Bangladesh, production of rice and wheat might drop by 8% and 32%, respectively, by the year 2050. Studies show that a 0.5°C rise in winter temperature could reduce wheat yield by 0.45 tons per hectare in India. Other studies suggest that 2–5% decrease in Indian wheat and maize yield potentials for temperature increases of 0.5–1.5°C could occur.

For countries in South Asia, the net cereal production is projected to decline at least between 4% and 10% by the end of this century under the most conservative climate change scenario. The changes in cereal crop production potential suggest increasing stress on resources induced by climate change in many of the developing countries of Asia. Climate change could affect not only the crop production per unit area but also the area of production. More than 28 Mha in South and East Asia will require a substantial increase in irrigation for sustained productivity and the demand for agricultural irrigation in arid and semi-arid regions of Asia is estimated to increase by at least 10% for an increase in temperature of 1°C.

Grasslands in the drylands of South Asia consisting of fast-growing, often short lived species, are sensitive to CO_2 and climate change, with the impacts related to the stability and resilience of plant communities (Mitchell and Csillag 2001). Experiments support the concept of rapid changes in species composition and diversity under climate change. In dry regions, there are risks that severe vegetation degeneration leads to positive feedbacks between soil degradation and reduced vegetation and rainfall, with corresponding loss of pastoral areas and farmlands (Zheng et al. 2002). The natural grassland coverage and the grass yield in Asia, in general, are projected to decline with a rise in temperature and higher evaporation (Lu and Lu 2003). Thermal stress reduces productivity, conception rates and is potentially life-threatening to livestock (Easterling et al. 2007).

Although climate change will impact the availability of forest resources, the anthropogenic impact, particularly land-use change and deforestation in tropical zones, is likely to be extremely important (Zhao et al. 2005). The mangrove forests along the Indus Delta in Pakistan are an especially diverse ecosystem. They provide fuelwood and fodder to local inhabitants and are breeding grounds for an estimated 90% of shrimps that are exported. Pakistan's national communication report states that detrimental impacts of climate change on rural livelihoods would result in more people being forced to seek employment in urban areas (MoE 2003). In Sri Lanka, Somaratne and Dhanapala (1996) estimate a decrease in tropical rain forest of 2–11% and an increase in tropical dry forest of 7–8%. This study also indicates that increased temperature and rainfall would result in a northward shift of tropical wet forest into areas currently occupied by tropical dry forest. Droughts combined with deforestation increase fire danger (Laurance and Williamson 2001).

2.3.5 Impacts on Crop Pests and Diseases

According to Cruz et al. (2007), some studies have shown that higher temperatures and longer growing seasons could result in increased pest populations in temperate regions of Asia. Warmer winter temperatures would reduce winter kill and increase insect populations. Overall temperature increases may influence crop pest and disease interactions by increasing pest and disease growth rates which would then increase the number of reproductive generations per season and by decreasing pest and disease mortality due to warmer winter temperatures, would make the crop more vulnerable. The report stated that climate change along with changing pest and disease patterns will affect how crop production systems react in the future.

2.3.6 Impacts on Fisheries

For fisheries, an increased frequency of El Niño events could likely lead to measurable declines in fish larvae abundance in the coastal waters of South and South-East

Asia (Cruz et al. 2007). This and other factors are expected to contribute to a general decline in fishery production in the coastal waters of East, South and South-East Asia. There is a potential to substantially alter fish breeding habitats and fish food supply and therefore the abundance of fish populations in Asian waters due to the response to future climate change to the following factors: ocean currents; sea level; sea-water temperature; salinity; wind speed and direction; strength of upwelling; the mixing layer thickness; and predator response.

2.3.7 Impacts of Sea Level Rise

Low-lying coastal cities will be at the forefront of impacts; vulnerable to the risks of sea level rise and storms. These cities include Karachi, Mumbai, and Dhaka – all of which have also witnessed significant environmental stresses in recent years. Higher seawater levels would also increase the risk of flooding due to rainstorms, by reducing coastal drainage. A rise in sea level would raise the water table, further reducing drainage in coastal areas. All these effects could have possibly devastating socioeconomic implications, particularly for infrastructure in low lying deltaic areas.

Noronha et al. (2003) provided a coastal district level ranking of vulnerability to one metre sea level rise in India by constructing a weighted index as an average of the share of land area affected in the total area of district; the share of population affected in the total population of the district; and the index of relative infrastructure development. The most vulnerable districts were found to be the metropolises of Chennai and Mumbai.

The population of Maldives mainly depends on groundwater and rainwater as a source of freshwater. Both of these sources of water are vulnerable to changes in the climate and sea level rise. With the islands of the Maldives being low-lying, the rise in sea levels is likely to force saltwater into the freshwater lens (Ministry of Environment and Construction 2005).

2.4 Conclusions

South Asia is one of the most vulnerable regions in the world to climate change in view of the huge population, the large number of poor facing food insecurity, inappropriate soil and management practices on marginal lands in the semi-arid regions leading to increasing rates of land degradation and the projected impacts of climate change on the agricultural, forestry and fisheries sectors. The coping capacity of the rural poor, especially in the marginal areas, is poor and there is a need to mainstream the good practices for adaptation to climate change into sustainable development planning in the region. Improved understanding of the climate change impacts, vulnerability and the adaptation practices to cope with climate change could help this process.

References

Ainsworth EA, Long SP (2005) What have we learned from 15 years of free-air CO_2 enrichment (FACE)? A meta-analysis of the responses of photosynthesis, canopy properties and plant production to rising CO_2. New Phytol 165:351–372

Breshears DD, Cobb NS, Rich PM et al (2005) Regional vegetation die-off in response to global-change-type drought. Proc Natl Acad Sci USA 102:15144–15148

Burke EJ, Brown SJ, Christidis N (2006) Modelling the recent evolution of global drought and projections for the twenty-first century with the Hadley Centre climate model. J Hydrometeorol 7:1113–1125

Cassman KG, Dobermann A, Walters DT, Yang H (2003) Meeting cereal demand while protecting natural resources and improving environmental quality. Annu Rev Environ Resour 28:315–358

Cruz RV, Harasawa H, Lal M, Wu S, Anokhin Y, Punsalmaa B, Honda Y, Jafari M, Li C, Huu N (2007) Asia. Climate change, 2007, impacts, adaptation and vulnerability. In: Parry ML, Canziani OF, Palutikof JP et al (eds) Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, pp 469–506

Easterling W, Aggarwal PK, Batima P, Brander KM, Erda L, Howden SM, Kirilenko A, Morton J, Soussana JF, Schmidhuber J, Tubiello FN (2007) Food, fibre and forest products. Climate Change 2007: impacts, adaptation and vulnerability. In: Parry ML, Canziani OF, Palutikof JP (eds) Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, pp 273–313

Easterling DR, Meehl GA, Parmesan C, Changnon SA, Karl TR, Mearns LO (2000) Climate extremes: observations, modelling, and impacts. Science 289:2068–2074

FAO (2009) The State of Food Insecurity in the World 2009. Food and Agriculture Organization of the United Nations, Rome, Italy

Fischer G, Shah M, van Velthuizen H (2002) Climate change and agricultural vulnerability. International Institute for Applied Systems Analysis, Vienna, Austria. Available online at: www.iiasa.ac.at/Research/LUC/JB-Report.pdf

Gan J (2004) Risk and damage of southern pine beetle outbreaks under global climate change. Forest Ecol Manag 191:61–71

Giorgi F, Bi X (2005) Regional changes in surface climate interannual variability for the 21st century from ensembles of global model simulations. Geophys Res Lett 32:L13701. doi:10.1029/2005GL023002

Giertz S, Diekkruger B, Jaeger A, Schopp M (2006) An interdisciplinary scenario analysis to assess the water availability and water consumption in the Upper Oum catchment in Benin. Adv Geosci 9:1–11

Gitay H, Brown S, Easterling W, Jallow B (2001) Ecosystems and their goods and services. Climate Change,2001, Impacts, Adaptation, and Vulnerability. In: McCarthy JJ, Canziani OF, Leary NA, Dokken DJ, White KS (eds) Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, pp 237–342

Government of Maharashtra (2005) Maharashtra floods 2005. http://mdmu.maharashtra.gov.in/pdf/Flood/statusreport.pdf (Accessed 3 Nov 2009)

Hassan R, Scholes R, Ash N (eds) (2005) Ecosystems and human wellbeing: volume 1: current state and trends. Island Press, Washington, DC, p 917

HDR (2006) Human Development Report 2006. Beyond scarcity: power, poverty and the global water crisis. United Nations Development Programme, New York

IPCC (2007) Climate Change 2007: the physical science basis. In: Solomon S, Quin D, Manning M, Chen X, Marquis M, Averyt KB, Tignor HL, Miller M (eds) Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, pp 1–996

Jablonski LM, Wang X, Curtis PS (2002) Plant reproduction under elevated CO_2 conditions: a meta-analysis of reports on 79 crop and wild species. New Phytol 156:9–26

Kelkar U, Bhadwal S (2007) South Asian regional study on climate change impacts and adaptation: implications for human development. Human Development Report Office, Occasional Paper. United Nations Development Programme

Kundzewicz ZW, Mata LJ, Arnell NW, Döll P, Kabat P, Jiménez B, Miller KA, Oki T, Sen Z, Shiklomanov IA (2007) Freshwater resources and their management. In: Parry ML, Canziani OF, Palutikof JP, van der Linden PJ, Hanson CE (eds) Climate Change 2007: impacts, adaptation and vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, pp 173–210

Kumar KSK, Parikh J (2001) Indian agriculture and climate sensitivity. Global Environ Change 11(2):147–154

Lal M (2003) Global climate change: India's monsoon and its variability. J Environ Stud Policy 6:1–34

Lal M, Meehl GA, Arblaster JM (2000) Simulation of Indian summer monsoon rainfall and its intraseasonal variability. Reg Environ Change 1:163–179

Laurance WF, Williamson GB (2001) Positive feedbacks among forest fragmentation, drought, and climate change in the Amazon. Conserv Biol 15:1529–1535

Lenton R (2004) Water and climate variability: development impacts and coping strategies. Water Sci Technol 49:17–24

Lepers E, Lambin EF, Janetos AC, Defries R, Achard F, Ramankutty N, Scholes RJ (2005) A synthesis of information on rapid land-cover change for the period 1981–2000. BioScience 55:115–124

Liu CZ (2002) Suggestion on water resources in China corresponding with global climate change. China Water Resour 2:36–37

Lu XR, Lu XY (2003) Climate tendency analysis of warming and drying in grassland of Northeast Qingzang Plateau of China. Grassland of China 24:8–13

May W (2004) Simulation of the variability and extremes of daily rainfall during the Indian summer monsoon for present and future times in a global time slice experiment. Clim Dynam 22:183–204

McGregor GR, Ferro CAT, Stephenson DB (2005) Projected changes in extreme weather and climate events in Europe. In: Kirch W, Menne B, Bertollini R (eds) Extreme weather and climate events and public health responses. Springer, Dresden, pp 13–23

MENR (Ministry of Environment and Natural Resources) (2000) Initial national communication under the United Nations Framework Convention on Climate Change: Sri Lanka. MENR, Government of Sri Lanka, Colombo

Ministry of Environment and Construction (2005) State of the Environment – Maldives 2005

Mirza MQ (2002) Global warming and changes in the probability of occurrence of floods in Bangladesh and implications. Global Environ Chang 12:127–138

Mitchell SW, Csillag F (2001) Assessing the stability and uncertainty of predicted vegetation growth under climatic variability: northern mixed grass prairie. Ecol Model 139:101–121

MoE (Ministry of Environment (2003) Pakistan's initial national communication on climate change. Islamabad: MoE, Government of Islamic Republic of Pakistan. http://unfccc.int/resource/docs/natc/paknc1.pdf

Narisma GT, Foley JA, Licker R, Ramankutty N (2007) Abrupt changes in rainfall during the twentieth century. Geophys Res Lett 34:L06710. doi:doi:10.1029/2006GL028628

Noronha L, Choudhri BS, Nairy KS (2003) Relative vulnerability of districts to a potential sea-level rise along the coastline of India. In TERI. 2003. Environmental threats, vulnerability and adaptation: case studies from India. TERI, New Delhi, pp 121–142

Paul B, Rashid H (1993) Flood damage to rice crop in Bangladesh. Geogr Rev 83(2):151–159

Peng S, Huang J, Sheehy JE, Laza RE, Visperas RM, Zhong X, Centeno GS, Khush GS, Cassman KG (2004) Rice yields decline with higher night temperature from global warming. P Natl Acad Sci USA 101:9971–9975

Petit JR, Jouzel J, Raynaud D, Barkov NI, Barnola JM, Basile I, Bender M, Chappellaz J, Davis M, Delaygue G, Delmotte M, Kotlyakov VM, Legrand M, Lipenkov VY, Lorius C, Pépin L, Ritz C, Saltzman E, Stievenard M (1999) Climate and atmospheric history of the past 420,000 years from the Vostok ice core, Antarctica. Nature 399:429–436

Ramanathan V (1975) Greenhouse effect due to chlorofluorocarbons: climatic implications. Science 190:50–52

Raut A (2006) Climate impacts on Nepal. Tiempo 60:3–5

Riebsame WE, Strzepek KM, Wescoat L Jr, Perrit R, Graile GL, Jacobs J, Leichenko R, Magadza C, Phien H, Urbiztondo BJ, Restrepo P, Rose WR, Saleh M, Ti LH, Tucci C, Yates D (1995) Complex river basins. In: Strzepek KM, Smith JB (eds) As climate changes, international impacts and implications. Cambridge University Press, Cambridge, pp 57–91

Schwierz C, Appenzeller C, Davies HC, Liniger MA, Müller W, Stocker T, Yoshimori M (2006) Challenges posed by and approaches to the study of seasonal-to-decadal climate variability. Clim Chang 79:31–63

Somaratne S, Dhanapala AH (1996) Potential impact of global climate change on forest in Sri Lanka. In: Erda L, Bolhofer W, Huq S, Lenhart S, Mukherjee SK, Smith JB, Wisniewski J (eds) Climate change variability and adaptation in Asia and the Pacific. Kluwer, Dordrecht, The Netherlands, pp 129–135

Stern N (2007) The economics of climate change: the stern review. Cambridge University Press, Cambridge, p 692

Stewart IT, Cayan DR, Dettinger MD (2004) Changes in snowmelt runoff timing in Western North America under a 'business as usual' climate change scenario. Clim Change 62:217–232

Stige LC, Stave J, Chan KS, Ciannelli L, Pretorelli N, Glantz M, Herren HR, Stenseth NC (2006) The effect of climate variation on agro-pastoral production in Africa. P Natl Acad Sci USA 103:3049–3053

Sultana H, Ali N (2006) Vulnerability of wheat production in different climatic zones of Pakistan under climate change scenarios using CSM-CERES-Wheat Model. Paper presented in the Second International Young Scientists' Global Change Conference, Beijing, 7–9 November 2006, organised by START (the global change System for Analysis, Research and Training) and the China Meteorological Administration

Tol RSJ (2001) Equitable cost–benefit analysis of climate change policies. Ecol Econ 36:71–85

Tubiello FN (2005) Climate variability and agriculture: perspectives on current and future challenges. In: Knight B (ed) Impact of climate change, variability and weather fluctuations on crops and their produce markets. Impact Reports, Cambridge, UK, pp 45–63

Twomey S (1977) Influence of pollution on shortwave albedo of clouds. J Atmos Sci 34: 1149–1152

Tyndall J (1861) On the absorption and radiation of heat by gases and vapours, and on the physical connection. Philos Ma 22:277–302

UNEP (United Nations Environment Programme) (2003) GEO year book 2003. UNEP, Nairobi

UNEP (United Nations Environment Programme) (2007) GEO yearbook 2007: an overview of our changing environment. UNEP, Nairobi, p 86

Vogel C (2005) Seven fat years and seven lean years? Climate change and agriculture in Africa. IDS Bull 36:30–35

Wang WC, Yung YL, Lacis AA, Mo T, Hansen JE (1976) Greenhouse effects due to man-made perturbations of trace gases. Science 194:685–690

Wetherald RT, Manabe S (2002) Simulation of hydrologic changes associated with global warming. J Geophys Res 107(D19):4379. doi:doi:10.1029/2001JD001195

Wijeratne MA (1996) Tea: plucking strategies. Planters chronicle: September 1996, p 443

Xiao GW, Liu Q, Xu Z, Sun, Wang J (2005) Effects of temperature increase and elevated CO_2 concentration, with supplemental irrigation, on the yield of rain-fed spring wheat in a semiarid region of China. Agr Water Manage 74:243–255

Zhao Y, Wang C, Wang S, Tibig L (2005) Impacts of present and future climate variability on agriculture and forestry in the humid and sub-humid tropics. Climatic Change 70:73–116

Zheng YQ, Yu G, Qian YF, Miao M, Zeng X, Liu H (2002) Simulations of regional climatic effects of vegetation change in China. Q J Roy Meteor Soc 128:2089–2114, Part B

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