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**Fighting climate change:
Human solidarity in a divided world**

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South Asian Regional Study on Climate Change Impacts and Adaptation: Implications for Human Development

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It is now increasingly realised that even with the currently agreed regime of emissions control, concentrations of greenhouse gases (GHG) are likely to rise over the next few decades and over the millennia. Climate change is likely to threaten all life forms on earth with the extent of vulnerability varying across regions and populations within regions. The impacts however are likely to fall disproportionately upon developing countries, in particular, the poor living within them. Reduced capacities to be able to effectively respond to increased climatic variability and change in the climate exacerbates vulnerabilities.

Changes in temperature and precipitation patterns and numerous other factors will impact both natural and human systems. Climate sensitive sectors like agriculture, forestry, water resources and coastal regions, and, human systems including human health, human settlements, industry and energy sectors will be drastically affected (IPCC 2001).

1. Development priorities in South Asia

Poverty alleviation is high on the agenda as a top development priority in most countries in South Asia. Population growth, paucity of resources, and lack of economic opportunities create pressures on ecologically fragile areas and natural resources. In India, the 10th Plan of the government has set a high growth target of 8% to induce rapid reduction in income poverty and attain ambitious human development goals. Though there have been considerable improvements in certain sectors regarding those on education and health, India still lags behind in addressing gender-sensitive indicators such as maternal mortality or the gender gap in secondary education, and the high incidence of human immunodeficiency virus/acquired syndrome (HIV/AIDS) and other infectious diseases. In Bangladesh, the percentage of people below the poverty line has decreased from 70.6 percent to 46.5 since 1973-74. The government plans to halve the proportion of people below the poverty line by 2010. Main areas of focus include promoting pro-poor growth, social development and good governance.

Bhutan has plans to achieve universal primary education by the year 2007. The primary school gross enrolment rate increased from 67 % in 1990 to 72 % in 2000. Significant improvements have also been achieved in terms of decreased infant and maternal mortality rates, lower child malnutrition and better access to clean drinking water. Health care coverage is as high as 90 % and there are plans by the government to further improve the delivery of health services.

Table 1 presents some indicators of poverty and vulnerability listed for the South Asian countries. While the number of people living in extreme poverty is projected to decline, a third of those still in extreme poverty in the year 2015 are projected to be living in South Asia (World Bank estimates). South Asia also has the highest prevalence of malnutrition among children under five years (Figure 1) and the lowest share of rural population with access to improved sanitation (Figure 2).

Table 1. Indicators of poverty and vulnerability for South Asian countries

	Daily per capita calorie supply (Kcal) in 1999	% population without sustainable access to improved water source in 2000	Malaria cases (per 100,000 persons) in 2000	% population living below US$1 a day (most recent year during 1990-2002)
Bangladesh	2201	3	40	36
Bhutan	..	38	285	..
India	2417	16	7	34.7
Nepal	2264	12	33	37.7
Pakistan	2462	10	58	13.4
Sri Lanka	2411	2	1110	6.6
Data source	WRI	UNICEF, UNDP HDR	UNDESA, WHO, UNDP HDR	WB, UNDP HDR

Figure 1. Prevalence of malnutrition (percentage of children under 5 years)

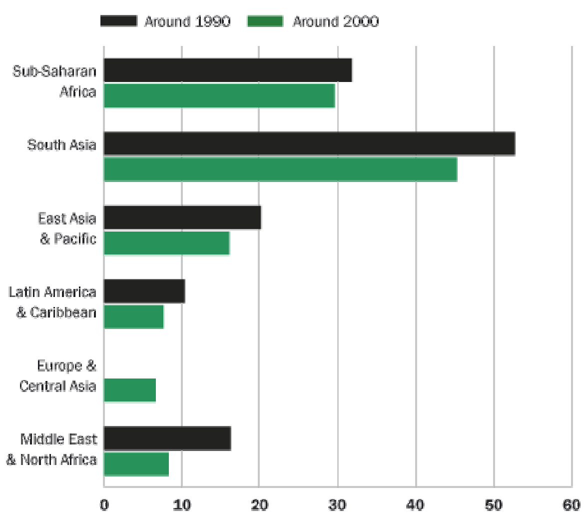
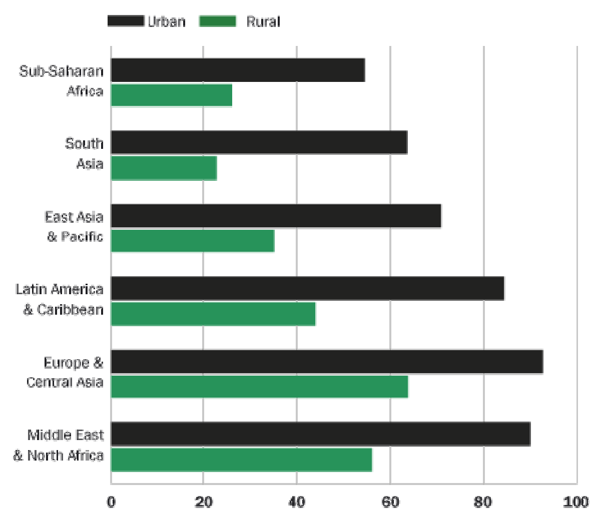


Figure 2. Percentage of population with access to improved sanitation in 2002



Source: World Bank Indicators

The Human Development Index (HDI) ranking for countries in South Asia indicates scope for social and economic development in the region (Table 2).

Table 2. HDI ranks of South Asian countries

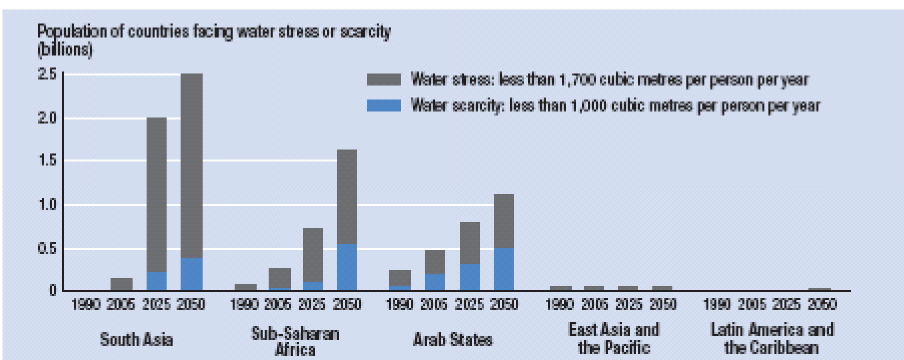
Country	HDI rank
India	127
Sri Lanka	93
Bangladesh	139
Nepal	136
Bhutan	134
Pakistan	135

Maldives	96

1.1 Sensitivity to climate change in the context of development challenges

The South Asian region is also highly sensitive to the consequences of climate change. It is known to be the most disaster prone region in the world supporting a huge population of more than 1.3 billion (UNEP 2003). This is critical as climate predictions for the future highlight increase in frequency and intensity of extreme weather events like droughts and floods (IPCC 2001); indicative of the huge population that is likely to be exposed and affected in the region. Analysis of rainfall data for India highlights the increase in the frequency of severe rainstorms over the last fifty years. The number of storms with more than 100 mm rainfall in a day is reported to have increased by 10 percent per decade (UNEP 2007). 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. Despite this, a decade of drought is also marked with certain regions in Asia getting affected. These conditions exacerbate and skew water availability across regions worsening conditions in regions that are already water stressed. Rapid depletion of water resource is already a cause for concern in many countries within the region. Figure 3 highlights that in South Asia alone, 2.5 billion people will be affected with water stress and scarcity by the year 2050 (HDR, 2006). While estimating these numbers, however, changes in climatic conditions have not been considered.

Figure 3. Projected stress in water availability across regions for the years 2025 and 2050



Source: HDR, 2006

The Himalayan range contains high altitude glaciers that supply water to many rivers in Asia. 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. In Nepal and Bhutan, melting glaciers are filling glacial lakes beyond their capacities contributing to Galcial Lake Outburst Floods (GLOFs) (UNEP 2007).

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, indicative of the well-being of millions. 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. There however has been striking differences in growth performance across countries.

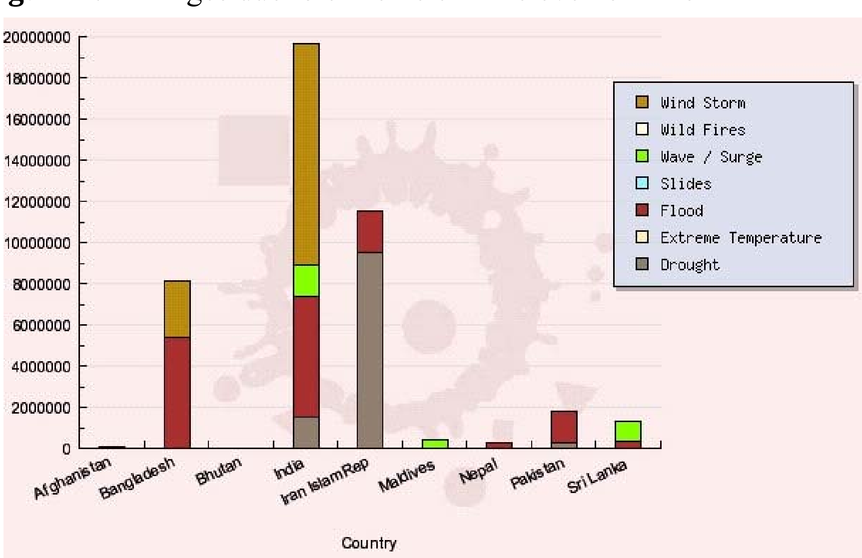
Countries	GDP growth			Agriculture		
	1971-1980	1981-1990	1990-2000	1971-1980	1981-1990	1990-2000
Bangladesh	1.9	4.6	4.8	0.5	2.7	2.9
Bhutan		7.8	6.1		4.9	3.2
India	3.4	5.5	6	2.1	3.7	3
Nepal	2.5	4.3	4.9	0.8	3.8	2.5
Pakistan	4.9	6.6	3.7	2.6	4.9	4.4
Sri Lanka	4.3	4.3	5.3	2.6	2.7	1.9

Source: Haq (2003)

With 19 % contribution to the country's GDP, agriculture in India employs two-thirds of the national workforce in the country. In addition, it caters to the needs of other agro-processing industries that form the backbone of the Indian economy. Serving as a major livelihood resource in the country, the sector plays a critical role in defining poverty levels across different states in the country (TERI 2007). GDP contributions in other South Asian countries are also found to be similar to that in India barring Nepal where the dependence is far higher. The sector is also the largest consumer of water in the region further sensitive to the consequences of a changing climate. In India alone, more than 85 % of the water is used for irrigation purposes.

High growth rates in the agriculture sector represent Pakistan as one of the high growth rate countries in the region. Correspondingly, Pakistan has observed a decline in rural poverty from 49 percent to 32 percent over the time period 1969 to 1998 (Haq 2003).

Figure 4. Damages due to extreme climate events in Asia



Source: OFDA-CRED (2005)

Bhutan and Nepal have fragile mountainous ecosystems; Bangladesh and Sri Lanka have low-lying coastal areas, while India and Pakistan depend on cultivation in arid and semi-arid lands. These countries already experience frequent natural disasters (Figure 4). The Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC 2001) pointed out that climate change and its variability will exacerbate existing vulnerabilities to droughts and floods in Asia. Tropical cyclones can become more intense. Combined with sea-level rise, this will result in enhanced risk of loss of life and properties in coastal low-lying areas of cyclone-prone countries. Increased precipitation intensity, particularly during the summer monsoon, can contribute to increase in flood events. At the same time, drier summer conditions in arid and semi-arid areas can lead to more severe droughts.

Livelihoods and economic activities in South Asia are closely tied to the natural resource base, and are hence, highly sensitive to changes in the climate. Agriculture and aquaculture will be threatened by a combination of thermal and water stresses, sea level rise, increased flooding, and strong winds associated with intense tropical cyclones. Freshwater availability and biodiversity, which are already under pressure due to population growth and land use change, will be further impacted by climate change. Finally, warmer and wetter conditions will increase the potential for a higher incidence of heat-related and infectious diseases.

By adversely impacting sectors like agriculture, water resources, and health, climate change presents a formidable challenge for efforts to reduce poverty and achieve the Millennium Development Goals in South Asia. The fundamental dilemma for the countries of South Asia is that prolonged or extreme climate stress can drive processes of impoverishment by affecting the livelihoods of poor people, while poverty increases vulnerability to climate change by further limiting options.

Box 1. Poverty and vulnerability to climate change

Through extreme or prolonged stress, climate variability and change can affect the quality, quantity, and reliability of many of the services natural resources provide. This in turn has a critical impact on food intake, health, and livelihoods of poor people. Climate variability can fundamentally drive processes of impoverishment through direct and indirect routes (IRI 2005):

1. Direct: Severe or repeated climate shocks can push vulnerable households into a persistent poverty trap when their individual coping responses involve divestment of productive assets such as land or livestock
2. Indirect: Climate uncertainty causes inability to anticipate when climatic extremes will occur, which acts as a disincentive to investment, innovation, and development interventions.

At the same time, poverty increases vulnerability to climate change by reducing options. The poor are typically forced to live in marginal lands (e.g. flood-prone, degraded soil, etc) and in living conditions which "are predisposing conditions to ill health". This includes low quality housing (e.g. lack of screen doors), bad sanitation, and unprotected sources of drinking water, which juxtaposed with undernourishment and deficient health care, makes them highly prone to vector- and water-borne diseases. The poor are generally dependent on subsistence activities involving extraction of natural resources, which are vulnerable to climate change. Most importantly, there is little accumulation of assets to draw on in times of stress.

2. Impacts of climate change on human well-being and development

With 2007 likely to be the warmest year on record (UK Met Office projections), it is important to take stock of the likely impacts of climate change on human well-being, livelihoods, and development in South Asia.

2.1 Adverse impact on food security and farm livelihoods

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. Landholdings are already very small due to large family sizes in this region. In the hills, in particular, holdings are also fragmented which prevent farmers from reaping economies of scale.

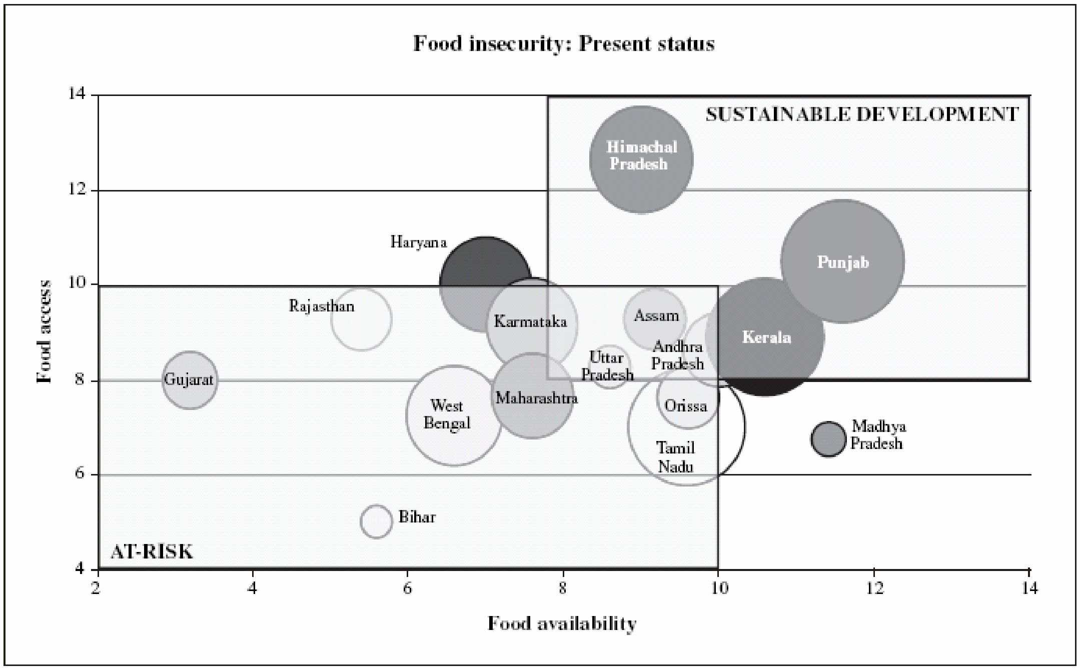
Table 3. Impacts of climate change on agriculture in India: summary of recent studies

GoI (2004)	Decline in yields are offset by increase in carbon dioxide concentrations with the magnitude varying from one crop to the other in different regions depending mostly on the scenario chosen. Wheat yields in central India may drop by 2% in a pessimistic climate change scenario.
TERI (2004)	Districts in western Rajasthan, southern Gujarat, Madhya Pradesh, Maharashtra, northern Karnataka, northern Andhra Pradesh, and southern Bihar are highly vulnerable to climate change in the context of economic globalization. Numerous physical (e.g. cropping patterns, crop diversification, and shifts to drought-/salt-resistant varieties) and socio-economic (e.g. ownership of assets, access to services, and infrastructural support) factors come into play in enhancing or constraining the current capacity of farmers to cope with adverse changes.
IPCC (2001)	Temperature rise of 1.5 degree centigrade and 2 mm increase in precipitation could result in a decline in rice yields by 3 to 15 %. Sorghum yields would be affected and yields are predicted to vary from +18 to -22 % depending on a rise of 2 to 4 degree centigrade in temperatures and increase by 20 to 40 % of precipitation.
Kumar and Parikh (1998)	Economic impacts would be significant even after accounting for farm-level adaptation. The loss in net revenue at the farm level is estimated to range between 9% and 25% for a temperature rise of 2 °C–3.5 °C.
Sanghi, Mendelsohn, and Dinar (1998)	A 2 °C rise in mean temperature and a 7% increase in mean precipitation would reduce net revenues by 12.3% for the country as a whole. Agriculture in coastal regions of Gujarat, Maharashtra, and Karnataka will be the most negatively affected. Possible losses are pointed out for the major foodgrain producing regions of Punjab, Haryana, and Western Uttar Pradesh.

India

Wheat yields in central India may drop by 2% in a pessimistic climate change scenario (GoI 2004). 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. **The major foodgrain producing regions of Haryana, Punjab and western Uttar Pradesh experience the most negative effects, along with the coastal districts of Tamil Nadu**. Punjab and Haryana are significant from the perspective of food security in India (Figure 5), but they also face severe depletion of groundwater resources due to intensive cultivation techniques introduced in the Green Revolution in the 1970s coupled with populist free power policies.

Figure 5. Rural food insecurity in India.



Food availability is based on production indicators for each state. Food access aggregates indicators of market exchanges. Size of each bubble corresponds to indicators of nutritional status.

Source: MSSRF

Pakistan

In the hot climate of Pakistan, cereal crops are already at the margin of stress. An increase 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. **Wheat yields are predicted to decline by 6-9 % in sub-humid, semi-arid, 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).

Sri Lanka

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 2000)**. In warm, semi-arid regions, deficiency of moisture would be a major constraint.** Most cropping activities for e.g., coarse grain, legumes, vegetables, and potato are likely to be affected adversely due to the impacts of climate change. The highest negative impact is estimated for coarse grains and coconut production. 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 metres** (Wijeratne 1996). With the tea industry in Sri Lanka being a major source of foreign exchange and a significant source of income for labourers the impacts are likely to be grave. More recently, under an ongoing AIACC project, Peiris et al (2004) confirmed that changes in monsoon rainfall pattern and increase in maximum air temperature are two key factors on the variability of coconut production in the principal coconut growing regions. The projected coconut production after 2040 in all climate scenarios, when other external factors are non-limiting, will not be sufficient to cater the local consumption for the increased population. Among the different stakeholders in coconut industry, the coconut oil (CNO) industry would be most affected.

Bangladesh
Karim et al (1996) projects a net negative effect on the yields of rice, the staple food of the population, in Bangladesh. 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).

Bhutan
Upland crop production, practised close to the margins of viable production, can be highly sensitive to variations in climate. Climate change will cause the cultivating zone to shift upwards to unsuitable steep slopes. It is also expected to increase the severity and frequency of monsoonal storms and flooding in the Himalayas, which could aggravate the occurrence of landslides. In addition to the danger to life and property, some of the generated sediments may be deposited in the agricultural lands or in irrigation canals and streams, which will contribute to deterioration in crop production and in the quality of agricultural lands (NEC 2000).

2.2 Increased risks to human health
Changes in climate may alter the distribution of important vector species (for example, mosquitoes) and may increase the spread of disease to new areas that lack a strong public health infrastructure.

India
Malaria is endemic in all parts of India, except at elevations above 1,800 metres and in some coastal areas. The principal malaria-prone areas are Orissa, Madhya Pradesh, Chhattisgarh, and the north-eastern parts of the country. According to the World Bank, in 1998 about 577,000 Disability- Adjusted Life Years (DALYs) were lost due to malaria. Presently, the transmission window (based on minimum required conditions for ensuing malaria transmission) is open for 12 months in eight states (Andhra Pradesh, Chhattisgarh, Karnataka, Kerala, Maharashtra, Orissa, Tamil Nadu and West Bengal), nine to 11 months in the north-eastern states (Gujarat, Haryana, Madhya Pradesh, Punjab, Rajasthan, Uttar Pradesh and Uttaranchal). The northern states of Himachal Pradesh and Jammu and Kashmir have transmission windows open for five to seven months, respectively. Considering a 3.8°C increase in temperature and a seven per cent increase in relative humidity by the 2050s (with reference to the present), nine states of India may have transmission windows open for all 12 months. **The transmission windows in the states of Jammu and Kashmir and Rajasthan may increase by three to five months** as compared to the base year. States like Orissa and some southern states, where the mean temperature is more than 32°C in four to five months, a further increase in temperature is likely to cut the transmission window by two to three months (GoI 2004). Other health vulnerabilities are summarized in Table 4.

Table 4. Known effects of weather / climate and potential health vulnerabilities due to climate change

Health concerns	Vulnerabilities due to climate change
Temperature-related morbidity	Heat- and cold-related illnesses Cardiovascular illnesses
Vector-borne diseases	Changed pattern of diseases Malaria, filaria, kala-azar, Japanese encephalitis, and dengue caused by bacteria, viruses and other vector-borne pathogens
Health effects of extreme weather	Diarrhoea, cholera, and poisoning caused by biological and chemical contaminants in the water (even today about 70% of the epidemic emergencies in India are water-borne) Damaged public health infrastructure due to cyclones / floods Injuries and illnesses Social and mental health stress due to disasters and displacement
Health effects due to food insecurity	Malnutrition and hunger, especially in children

Source: GoI (2004)

Maldives

Although malaria has been eradicated from the Maldives, climate change is likely to induce a threat of malaria outbreaks. Poor sanitation in the islands of Maldives along with conducive environment for the spread of diseases might lead to the outbreak of water related and waterborne diseases such as diarrhoea (Ministry of Environment and Construction 2005).

Nepal

Greater risk of kalaazar and Japanese encephalitis is highlighted in the Nepalese National Communication (DHM 2004). The **subtropical and warm temperate regions are predicted to be particularly vulnerable to malaria and kalaazar**. There will be higher risk of water-borne diseases due to poor sanitation and higher rainfall. Increased flooding could damage municipal treatment facilities or land-fills, increasing the risk of contamination.

Sri Lanka

Expansion and shift in malarial transmission zones is expected. Moreover, the seasonal pattern of malaria transmission is likely to undergo a change, from the high transmission season which now occurs from November to February being curtailed, and the minor mid-year peak being enhanced with high rates of transmission occurring in September. **Areas bordering the non-endemic wet zone of the country are likely to become highly vulnerable to malaria** (MENR 2000).

Pakistan

A recent study for Pakistan also points out that long warm spells are likely to become more frequent under a doubled CO2 climate change scenario (Islam and Rehman 2006).

The mountainous regions of South Asia are particularly vulnerable to temperature rise and associated climate changes. High altitude populations that fall outside areas

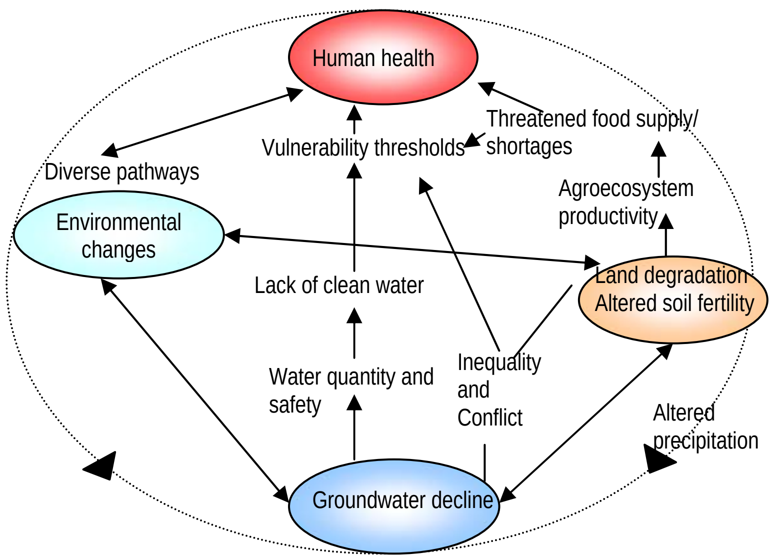
of stable endemic malaria transmission may be particularly vulnerable to increases in malaria, due to climate warming. Table 5 highlights health determinants and outcomes for these regions.

Table 5. Health determinants and health outcomes that currently exist in mountain regions (synthesis of country reports)

	Bangladesh	Bhutan	Nepal	India
Heat waves	+	-	+	+
Glacial lake floods	-	M	M	M
Flash floods	+	M	M	M
Riverine floods	+	-	+	+
Malaria	+	+	M	+
Japanese encephalitis	+	-	+	+
Kala azar	-	-	+	+
Dengue	+	+	-	+
Water-borne diseases	+	M	M	M
Water scarcity, quality	+	+	M	M
Drought-related food insecurity	+	-	-	M

Note: "M" indicates that the health determinant or outcome is present in the mountainous region of the country (and also in the non-mountainous areas)
"+" indicates that the health determinant or outcome is present elsewhere in the country
"-" indicates that the health determinant or outcome is not present in the country.
Source: WHO (2005)

Figure 6. Interactions between economic activities, environmental degradation, and human health: example of mining in Goa, India



Source: D'Souza (2006)

These impacts will exacerbate existing health problems (Figure 6) and pose a great challenge in view of the poor access to health services in South Asia, particularly for communities living in rural areas or remote areas such as mountains and islands.

2.3 Growing pressures on coastal cities

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. As climate change will adversely impact farm livelihoods, migration to urban areas in search of economic opportunities is likely to increase, putting greater pressure on scarce housing, water, sanitation facilities, and energy services. These concerns are exemplified by the July 2005 floods in Mumbai, India's commercial capital, caused by a record level of precipitation within 24 hours, which brought life to a standstill and resulted in economic losses of Rs 90 billion (Box 2). Similarly, **Pakistan's port city Karachi is highly vulnerable to increased monsoonal and tidal activity, resulting in periodic flooding.** The National Communication of Pakistan (MoE 2003) warns against significant flooding impacts in the coastal zone, particularly in the low-lying deltaic regions. These areas would become more vulnerable to flooding because high sea levels provide a higher base for storm surges to build upon. 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.

The Indian National Communication (GoI 2004) assessed the extent of vulnerability of coastal districts based on physical exposure to sea-level rise, social aspects related to population affected and extent of economic activities in coastal areas and the capacity to cope in these regions. Using global models, sea level rise of 10-25 cm per 100 years has been predicted under a greenhouse scenario. To separate the influences of global climatic changes the available mean sea level historical data has been evaluated for 10 locations for a period ranging from 1920 to 1999**. The rise in sea levels is reported to be highest in the Gulf of Kutch and the coast of West Bengal. While West Bengal ranks first in terms of frequency of occurrence of cyclones, Chennai ranks first if normalised with respect to area and Karaikal in Pondicherry ranks first with respect to coastline length.** Noronha et al (2003) provided a coastal district level ranking of vulnerability to one metre sea level rise by constructing a weighted index as an average of:

- Share of land area affected in the total area of district
- Share of population affected in the total population of the district
- index of relative infrastructure development

The most vulnerable districts were found to be the metropolises of Chennai and Mumbai (Figure 7).

Figure 7. Average index of vulnerability for coastal districts of India

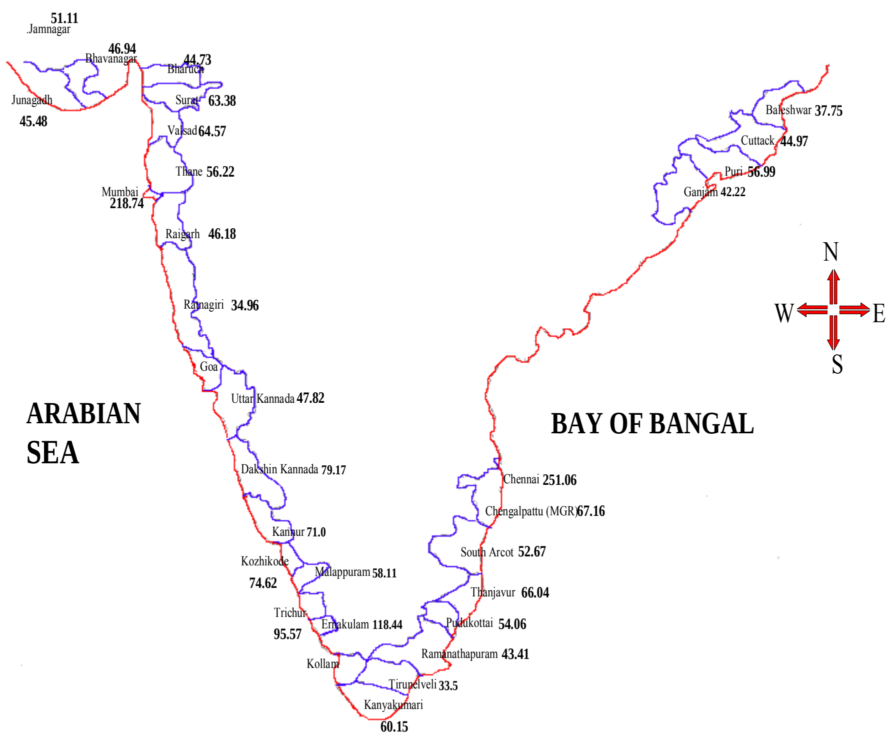


Fig. 4. Map showing Values of Average Index of vulnerability for Coastal Districts of India

Box 2 Insurance losses due to Mumbai floods in 2005

The July 2005 floods in India's commercial capital not only brought life to a standstill but also resulted in estimated losses of over 90 billion rupees. Of these, the loss to insurance companies was estimated to be 25 billion rupees, 10 billion rupees to the pharmaceuticals industry, and 1 billion rupees to airlines. The largest corporate claim was for the Patalganga plant of Reliance Industries. There were claims from damages to and losses of motor vehicles, flooding in ground-level homes and bungalows, damage to assets in shops and stocks in godowns, machinery, and loss of profit for businesses. The fire at Oil and Natural Gas Corporation's Bombay High platform on 27 July 2005 caused oil production to drop from 261 000 bpd (barrels per day) to 142 000 bpd. The platform was insured for 195 million dollars, and the multipurpose support vessel that sank after colliding with the oil-drilling platform was insured for 60 million dollars – a total of 255 million dollars. ICICI Lombard admitted that the events would have some impact on premium rates. It was even reported that general insurance companies were considering the withdrawal of flood cover in the light of heavy losses in Mumbai. This, however, was denied by the IRDA (Insurance Regulatory and Development Authority). Insurers announced steps to ensure speedy settlement of claims by setting up special cells besides waiving some procedural requirements. To enable rejuvenation of businesses, the IRDA said that insurance companies have allowed 'on account' payments where the survey was likely to take time. The IRDA also raised the limit of losses required to be surveyed by a licensed surveyor and loss assessor for settlement of claims, from 20 000 to 50 000 rupees.

Sources: Halarnkar and Chatterjee (2005), The Hindu (2005), Deccan Herald (2005), Financial Express (2005), IRDA (2005), Ishrati (2005)

2.4 Declining water resources

According to the IPCC, the greatest vulnerability to climate change is in unsustainably managed ecosystems that are currently water stressed. **By 2050, the annual runoff in the Brahmaputra is projected to decline by 14%, and that in the Indus by 27%** (IPCC 2001), which will have tremendous downstream consequences. Increased warming might result in increased flows initially with reduced flows later as the glacier disappears. Available records suggest that Gangotri glacier is retreating by about 30 m yr-1. A warming is likely to increase melting far more rapidly than accumulation. Glacial melt is expected to increase under changed climate conditions, which would lead to increased summer flows in glacier fed river systems for a few decades, followed by a reduction in flow as the glaciers disappear. India, Bhutan and Nepal are concerned about the reduction in flow of snow-fed rivers (respective NCs), while Maldives is threatened by saltwater intrusion into freshwater (NC of Maldives). In Pakistan, a 6% decrease in rainfall will increase the net irrigation requirement for wheat by 29% (NC of Pakistan). Increased glacial melt due to warming is also predicted to affect river flows.

Table 5. Impacts of climate change on water resources in India: summary of recent studies

GoI (2004)	Decline in total run-off for all river basins except Narmada and Tapi. A decline in run-off by more than two-thirds the amount in the control scenario has been predicted for the basins of Sabarmati and Luni with severe drought conditions prevalent in a futuristic climate scenario.
Indo-UK programme	Except for Godavari, where there are not any significant changes reported in the annual cycle of rainfall, the Ganges and the Krishna basins show major declining trends which is an interesting observation at a basin scale.
Narula and Bhadwal 2003	A decrease of 20% to 30% in total flows in the Lakhwar sub-basin in Uttaranchal on account of climate change alone was estimated.
Lal et al (2001)	Studied the impact of climate change on water resources using outputs from various GCMs
Tangri and Hasnain (2003)	Examined the impact on glaciers in the Himalayan region
Wilk et al (2002)	Studied impacts on mean annual run-off and assured water yields for a reservoir in southern India

Bangladesh

As floods in Bangladesh are caused by intense monsoon precipitation over the basin areas of the Ganges, Brahmaputra and Meghna (GBM) rivers, future changes in precipitation regime have four distinct implications:

1. the timing of occurrence of floods may change, with a possible change in the seasonality of the hydrological cycle
2. increased precipitation in the GBM basins may increase the magnitude, depth, and spatial extent of floods
3. timing of peaking in the major rivers may also change that may change the likelihood of synchronization of flood peaks of major rivers
4. increased magnitude, depth, extent and duration of floods will bring a dramatic change in land-use patterns in Bangladesh.

A study carried out under the BDCLIM (Bangladesh Climate) project sought to examine possible changes in flooding in Bangladesh under a given climate scenario. IPCC (2001) indicates that the average annual runoff in the Brahmaputra basin would decline by 14% by the year 2050 as a result of climate change. Nishat (2002) made an attempt to examine the implications of climate change for the National Water Management Plan of Bangladesh. Impacts include excessive rise in evaporation rates, reduction in dry season trans-boundary flows resulting in an increase in irrigation water requirements, sea level rise of 0.5m to exacerbate drainage congestion, and other potential impacts such as more frequent flash floods, higher frequency of tropical cyclones, rise in storm surge depths, and slower accretion of new coastal lands.

Bhutan

The availability of water in Bhutan is heavily dependent on heavy rainfall, glaciers or snow, land use practices, and user demand. A reduction in the average flow of snow-fed rivers, combined with an increase in peak flows and sediment yield, would have major impacts on hydropower generation, urban water supply, and agriculture. An increase in rainfall intensity may increase run-off, enhance soil erosion, and accelerate sedimentation in the existing water supplies or reservoirs.

Nepal

A preliminary analysis of river discharge shows decreasing trends for Karnali and Sapta Koshi but increasing trends for Narayani (DHM 2004).

Box 3. Draining potentially dangerous glacial lakes in Nepal

Of 2,323 glacial lakes in Nepal, 20 have been found to be potentially dangerous with respect to glacial lake outburst floods The most significant such event occurred in 1985, when a glacial lake outburst flood caused a 10-15 metre 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. As a response to Nepal’s vulnerability to climate change, numerous adaptation options for various sectors have been proposed and many already implemented. One major project that focuses on glacial lake outburst flood mitigation has been undertaken in the Tsho Rolpa glacial lake area. With Dutch support, the Nepalese government undertook a project to drain and reduce the depth of the Tsho Rolpa glacial lake by 3 metres. This reduced the risk of a glacial lake outburst flood by 20 percent. A major aspect of the design was that a channel was cut into the moraine, and a gate was constructed to allow water to be released as necessary. In addition, an early warning system was simultaneously established in 19 villages downstream of the Rolwaling river. Local villagers were actively involved in the design of this system to ensure that they feel safe from potential flood events and are also made aware about the potential damages. Source: Raut (2006)

Maldives

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).

Pakistan

Wescoat (1991) studied the potential impacts of climate change on the Indus River basin. The study concluded that the total annual run-off from the upper basin is likely to increase by 11% to 16%. It estimated that although increased run-off could be advantageous for water supply and hydropower production it could aggravate problems of flooding, waterlogging, and salinity in the upper basin. Also, **even with an overall water surplus, shortages might occur in local areas of the highly productive Punjab rice–wheat zone and in the unglaciated valleys of the upper basin.** These areas currently lack adequate storage, conveyance, and irrigation management. Studies also indicate a negative impact on cotton, detrimental to the economy as it is the main cash crop of Pakistan.

Sri Lanka

Studies indicate that much of the water from heavy rainfall events in Sri Lanka would be lost as run-off to the sea.

Box 3. Climate variability and water stress in the Uttaranchal Himalayas

The Lakhwar river basin lies in the mid-Himalayan ranges in the north Indian state of Uttaranchal. While only 14% of the cultivable area in the hills is irrigated, the region has had a tradition of harvesting water from springs, snowfed streams, and rainfall. However, a 1996 study found that in about half of Uttaranchal’s villages, springs have either ceased to yield water or do so only in the rainy season. Under the HadRM2 scenario, this region is predicted to experience a net decrease in the volume of rainfall as well as a decline in the intensity of rainfall in 2041-60 compared to 1961-98. There is likely to be an increase

in the number of days of light intensity rainfall that is lost in satisfying soil moisture needs, while the heavier rainfall events needed to generate runoff become less frequent. It is estimated that total flows will be reduced by 20-30% under this climate change scenario. The potential impacts could be reduction in ground and surface water availability, level of crop yields and water quality. Community interactions revealed the general perception that rainfall has declined and the onset of the monsoon has become erratic. There was concern that rainfall is lost to surface runoff, streams and springs are drying up, and soil moisture has declined. In response to changing economic incentives, the cropping pattern has changed from a mix of crops for self-consumption to predominantly maize, but there is little profit from agriculture due to the fragmentation of landholdings in the hills, lack of labour due to migration to cities, and absence of irrigation facilities.
Source: Narula et al (2004), Kelkar et al (2006)

2.5 Damages due to natural disasters
As mentioned before, the countries of South Asia are already highly exposed to the risk of natural disasters. The high variability of monsoon climate causes a high frequency of climate related disasters, such as the floods, drought and heat waves. These impacts have hazardous implications for dams built in mountainous areas, tourism-based occupations in coastal areas, and agriculture in flood-prone areas. The economic magnitude of such impacts cannot be understated, for instance, Bangladesh lost about half a million tonne of rice, or 30% of the country's average annual foodgrain imports, each year due to floods during 1962-88 (Paul and Rashid 1993). In 1998, prolonged flooding resulted in estimated losses worth 1.5% of the GDP (Mirza 2002).

India
The vulnerability of India's coastal areas is highlighted in Jagatsingpur, where loss of mangroves due to biotic and abiotic pressures in the past few decades has left the coast exposed to the fury of cyclones and storm surges. **Household surveys in Orissa, indicate fall in production levels due to floods by 67 % in the kharif season.** Incidence of sickness, mainly water borne illness such as cholera, diarrhoea and dysentery are reported due to poor sanitation, poor sewerage systems and access to potable drinking water facilities during floods. Households cope by reducing food intake to maintain their food supplies for the duration of the flood. Expenditure shifts from food consumption towards shelter and medicine. The flood also manifests itself in a breakdown of livelihoods and the ensuing economic compulsions have a direct bearing on the education of children. 40% school dropouts were recorded in Sunadiakandha village of Orissa. Children are forced to withdraw from school and engage in work. Moreover, the flooding of school structures also leads to the suspension of education at least till the floodwaters recede. Other livelihood sources are also impacted to varying degrees. Farming households attempt to reduce expenditure by cutting back on labour hiring. Incomes from dairy activities decrease often because of livestock mortality and sale of cattle in the wake of floods. Lack of education restricts the opportunity to migrate elsewhere in pursuit of better employment avenues into skilled jobs (TERI 2007). Other studies have also shown that households in debt are likely to adopt livelihood options that provide quick returns but low returns. E.g. they may accept local, low-wage, casual work

rather than travel long distances to find buyers for their hand-made crafts (Nabarro et al 1990).

Bhutan

In Bhutan, the entire northern upper land has glacier/snow-fed lakes in the mountaintops. Increased temperature and greater seasonal variability in precipitation will lead to accelerated recession of glaciers and result in increase in the volume of these lakes (IPCC 1998). This might result in flash floods causing severe damages in terms of loss of lives, economy, and infrastructure in the valley. In 1994, a glacier lake outburst in the Lunana region flooded and damaged everything in the lower valleys of Punakha and below, illustrating the high degree of vulnerability to such extreme events.

Nepal

A survey done by ICIMOD and UNEP, highlights that 26 lakes in Nepal are categorised as dangerous due to threat to glacier lake outburst floods (GLOFs) (WWF 2005). As highlighted by IPCC (2001), glacial melt is expected to increase under changed climate conditions, which would lead to increased summer flows in some river systems for a few decades, followed by a reduction in flow as the glaciers disappear. DHM (2004) found that almost 20% of the present glaciated area above 5000 m altitude is likely to be snow and glacier free with an increase of air temperature by 1ºC. Similarly, a 3-4ºC temperature rise would result in the loss of 58 to 70 % of snow and glaciated areas with threat of GLOFs. Shrestha et al (2003) revealed increasing number of flood days and consecutive days of flood events in Nepal, and 26 lakes have been identified as dangerous with respect to glacier lake outburst floods (WWF 2005). Haritashya et al (2006) used remote sensing techniques to observe surging and variation in the frequency and size of supra-glacial lakes in the Hindukush and Karakoram Himalayas. In **Putalibazar municipality of Syangja district, Nepal, disaster losses show an increasing trend over the last 20 years not only due to a recorded increase in rainfall but because of increased settlements in the floodplains and improper road construction** (Shreshtha 2006).

Maldives

Beach erosion is now among the most serious environmental issues facing the islands of Maldives. On many islands, the sand at the beach and shoreline are being washed off at a greater rate than it is accreted. The process of coastal erosion and accretion is extremely complex with interrelations to climatic, geological, oceanographic, biological and terrestrial processes affecting the growth and stability of the reefs and island structures. Over 80% of the land area in the Maldives is less than 1 m above mean sea level. Being so low-lying, the islands of the Maldives are very vulnerable to inundation and beach erosion. Presently, **50% of all inhabited islands and 45% of tourist resorts face varying degrees of beach erosion.** Coastal infrastructure is also highly vulnerable to the impacts of sea level rise and extreme events. Given the geophysical characteristics of the islands and the population pressure, all human settlements, industry and vital infrastructure lie close to the shoreline. According to the State of Environment 2004, **more than 73% of the inhabited islands have buildings less than 100 feet away from**

the shoreline. 2 % of the islands have building right at the shore line. And more than 55 % of the islands have buildings less than 50 feet from the shoreline.

Sri Lanka
Significant erosion is already evident on many of Sri Lanka's beaches. This is likely to increase significantly with accelerated sea level rise. A rise in sea level would tend to cause a shoreline recession except where this trend is balanced by the influx of sediment. In a 30 cm sea level rise scenario, the study projects a possible shoreline recession of about 30 m and for a 100 cm scenario, the shoreline retreat is expected to be about 100 m. A one metre rise in sea level could drown most of the coastal wetlands in Sri Lanka. Another important concern is related to the intrusion of salt water. **Salt-water intrusion is already affecting approximately 15,000 hectares of paddy fields in the Galle district.** Sea level rise would also have adverse effects on infrastructure facilities, such as ports, harbours, and coast protection structures. MENR (2000) reports that the extent of land loss due to 0.3 to 1 m sea level rise in Sri Lanka is as follows:

Table 6. Sea level rise scenarios for Sri Lanka

SLR scenario	Land loss on south west coast (sq km)	Area inundated around lowlands adjacent to marshlands, lagoons, and estuaries of south-west coast (sq km)
0.3	6.0	41.0
1.0	11.5	91.25

Moreover, high intensity rainfall will contribute to short term inundation with impacts on life and infrastructure. Flash floods would be a significant problem in low-lying areas, while in hilly areas the problems may be landslides and destabilization of road/rain embankments (MENR 2000). **A high resolution multiple hazard analysis (World Bank 2005) showed marked spatial variability, with the hotspots including Kegalle and Ratnapura districts in the south west, and Ampara, Batticaloa, Trincomalee, Mullaitivu, and Killinochchi districts in the northeast.**

2.6 Shifting forest patterns

Climate change will aggravate existing human pressures on forests. Shifts in vegetation patterns could reduce the production and supply of timber and non-timber forest products. There could be a higher burden on highland grazier communities who will need to cover greater distances in search of pastures. Mangrove forests which provide fodder and fuelwood to local inhabitants are also vulnerable.

Pakistan
The vulnerability of Pakistan's coastal mangrove forests to the rise in sea level is a matter of great ecological concern. **The mangrove forests along the Indus Delta 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).

Sri Lanka

The climate change scenarios predicted for Sri Lanka indicate significant changes in temperature and precipitation by the year 2070. The forest composition is likely to change and affect timber production. Somaratne and Dhanapala (1996) estimate a decrease in tropical rainforest 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. **The most vulnerable forest areas in Sri Lanka are likely to be the Sinharaja Forest Reserve and Peak Wilderness Forest Reserve.** These changes would probably lead to the elimination of most Sri Lankan endemic species. With a likely increase in extreme events like droughts, the incidence of forest fires may also increase. Favourable conditions for pests and diseases might impact the quality of forests. Threat to mangroves due to rise in 20 cm sea level is also predicted.

India

The National Communication (GoI 2004) presented the impact of climate change on forests using BIOME 3 model for about 1500 grids (50 km X 50 km scale). The study predicted the equilibrium composition of different vegetation types under the control and the greenhouse scenario run. The underlying hypothesis of the model was that a combination of vegetation types to achieve the maximum Net Primary Productivity (NPP) represents the equilibrium vegetation. The results show shifts in forest boundary, changes in species assemblage or forest types, changes in net primary productivity, possible forest die-back in the transient phase, and potential loss or change in biodiversity. An increase in area under xeric shrublands and xeric woodlands replacing dry savanna is indicated in central India. Enhanced levels of CO_2 are projected to result in an increase in the NPP of forest ecosystems over more than 75 per cent of the forest area. Even in a relatively short span of about 50 years, most of the forest biomes in India seem to be highly vulnerable to the projected change in climate. About 70 per cent of the vegetation in India is likely to find itself less than optimally adapted to its existing location, making it more vulnerable to the adverse climatic conditions as well as to the increased biotic stresses. Biodiversity is also likely to be adversely impacted. These impacts on forests will have adverse socio-economic implications for forest-dependent communities and the national economy. The impacts of climate change on forest ecosystems are likely to be long-term and irreversible. Thus, there is a need for developing and implementing adaptation strategies to minimize possible adverse impacts. Further, there is a need to study and identify the forest policies, programmes and silvicultural practices that contribute to vulnerability of forest ecosystems to climate change.

A smaller study focussing on the Doon Valley in northern India (Negi 2000) shows that a sudden rise in both maximum and minimum temperatures has been recorded during 1951-60, owing to increased deforestation around Doon valley during the decade. The percentage contribution of evergreen species was 69% in 1958, which has reduced to

24% by 1998. While on the other hand the contribution of deciduous species increased from 31% in 1958 to 76% by the year 1998. This is again attributed to increase temperatures followed by reduction in total rainfall, which causes moisture limitations in the region, a situation favourable for deciduous species. The study reflects a 19% reduction in forest corridor in the region from 1960 onwards. The changing environment of Doon valley has ultimately altered the microclimate of sal forest from moist to dry in the Dehradun Forest division range, this has led to mass scale mortality in moist sal. The gaps created are being colonized with Mallotus phillipensis, Miliusa velutina and Ehertia laevis, which is expected to provide favourable conditions in due course of time for cycling succession of Shorea robusta, if protected.

Box 4. Observed shifts in forest patterns in Uttarkashi Forest Division, India

Mountain ecosystems have been shown to be some of the most vulnerable to climate change both from an ecological and a socio-economic perspective (Deshingkar et al. 1996). People who reside in these areas tend to be more dependent on their forest resources for a livelihood as it is harder to cultivate the land. Ecological communities in mountainous areas are strongly regulated and defined by climatic factors such as temperature and precipitation. Paul et al (2003) assessed the nature and extent of climate-induced vegetation change in Uttarkashi Forest Division of Uttaranchal and its consequent impacts on the livelihoods of communities in the region.

The Uttarkashi Forest Division lies between the latitudes 30025'N and 310 27'N and longitudes 780 9' E and 79025'E. The dependence of the people on forests is very high: they depend on the forests for fodder, grazing of animals, fuelwood and small timber. The study shows that there has been a discernable change in the climate of the study area in recent decades. The main trends indicate a decrease in precipitation especially over higher altitudes, change in precipitation pattern, warming leading to milder winters, warmer springs and the recession of glaciers. The observed changes in climate correspond with observed changes in the phonology of some species in the study area. The phonological changes taking place in this region, namely the earlier flowering and fruiting of various species and the implied lengthening of the growing season is likely to affect the distribution and availability of various non-timber forest products.

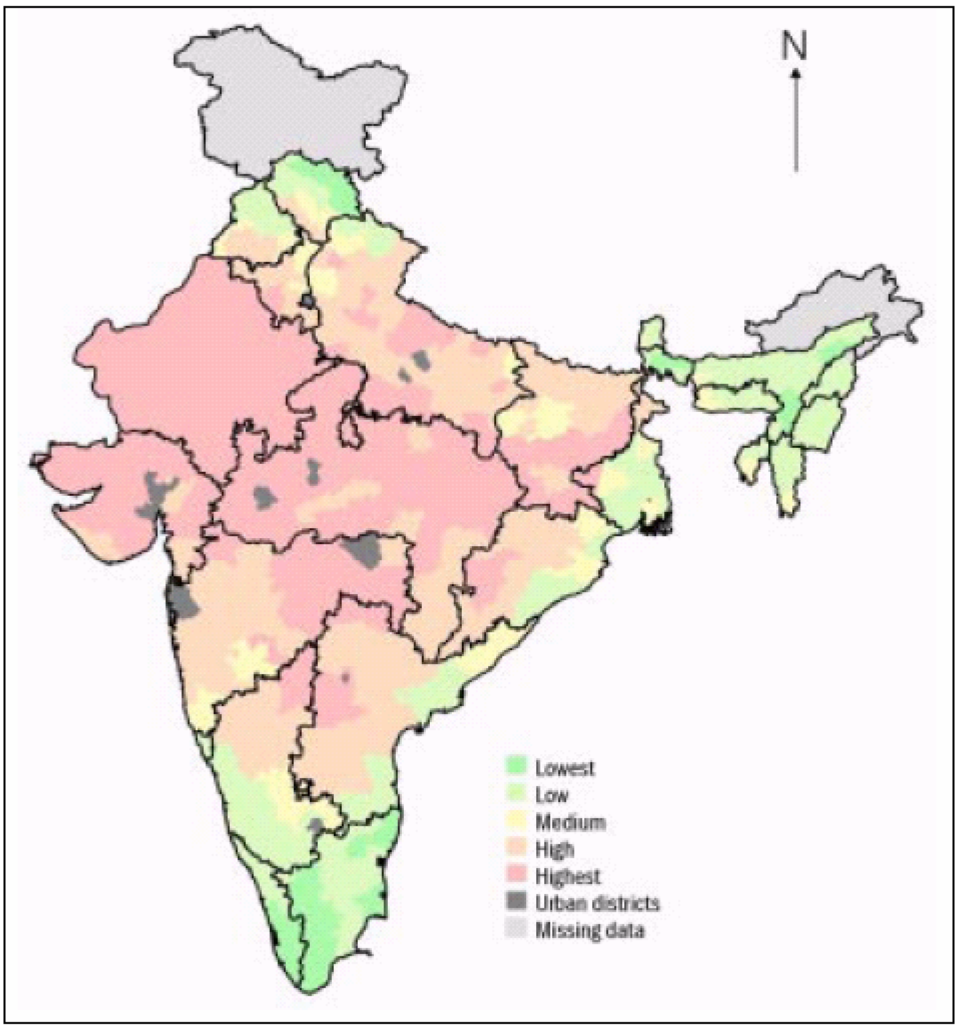
One of the observations made at lower elevations was that in the area around Saur village, Jalkurgad Block (compartment- 29), Chir (Pinus roxburghii) had begun to grow in areas formerly occupied by ban oak (Quercus leucotricophora). About 50 years ago, the stand used to be about 90% oak and mixed species and only 10% pine cover, according to local elders. Now they say the proportion of pine has increased to 50% by replacing the other species. The pine at this site appeared to be about 30 years of age. The respondents attributed this change mainly to a gradual increase in temperature and the consequent drying out of the soil. . The replacement of mixed species forests and oak forests by Chir pine leads to a significant decrease in the quality and availability of fodder for livestock, clean water and good fuelwood. The large root systems of Chir pines also draw down the water tables.

3. Coping with a changing climate: current capacity and limitations

While the previous section highlighted the likely impacts of climate change and increased climate variability, people in South Asia are already coping with current levels of climate variability. But it must be recognized that there are wide disparities in the capacity to adapt, and that access to adaptation options is severely constrained by economic resources, technological factors, access to information and skills, infrastructure, and institutions. Enhancing the capacity to cope with current stress can also help adapt to future changes to some extent.

Conditions worsen with reduced capacity of human systems to cope with changes. Many countries in South Asia vulnerable to the changes in the climate are also under pressure due to high rates of population growth, poor living conditions and deep embedded poverty. A multi-agency consultation draft (AfDB et al 2002) brought out at COP-8 highlighted that the adverse effects of climate change shall neutralise the efforts to achieve the Millennium Development Goals thereby increasing the vulnerability of the poor. Kartha et al (2006) mention that the communities most vulnerable to impacts are the poorest in the society and that climate change hinders the prospects of their development in the absence of proactive adaptation.

Figure 8. Vulnerability of Indian agriculture to climate change



Source: O'Brien et al (2004), TERI (2003)

In a detailed study of district-level vulnerability of Indian agriculture, adaptive capacity was mapped as a composite of biophysical, socioeconomic, and technological factors, and juxtaposed against a map of sensitivity to climate change (using output from the HadRM2 downscaled general circulation model). The map (Figure 8) revealed higher degrees of adaptive capacity in districts falling in the Indo-Gangetic plains (except for Bihar) and lower degrees of adaptive capacity in the interior regions of the country, including districts in Bihar, Rajasthan, Madhya Pradesh, Maharashtra, Andhra Pradesh, and Karnataka (O'Brien et al 2004).

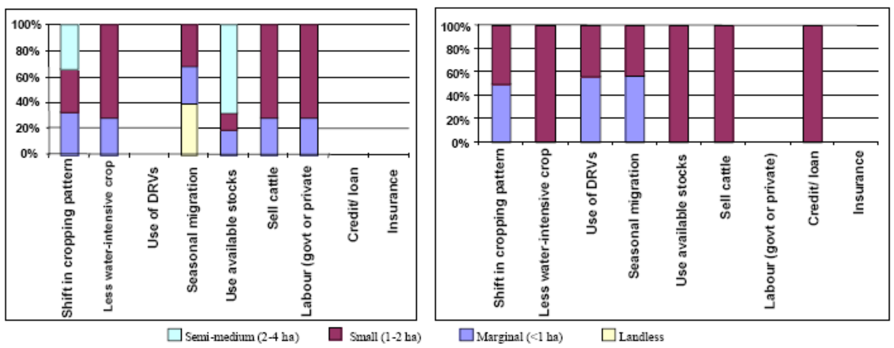
Community-level case studies carried out in highly vulnerable districts brought out the wide disparities in adaptive capacity across villages, across communities in villages, and specifically across individuals depending on land holding size, education, caste, etc. While larger farmers are able to benefit from government subsidies (e.g. for drip irrigation), formal bank credit, crop insurance, and access to larger markets, smaller farmers are disadvantaged due to lack of information and dependence on local merchants for credit.

In Anantapur district in Andhra Pradesh, groundnut is the principal crop but farmers were facing a crisis due to growing import competition and stagnating market prices, which coincided with a multi-year drought. Farmers are unable to shift to production of more profitable crops, due to lack of alternative, drought-tolerant, and economically viable crops. Rainfed crops (such as different fruit varieties), which could be economically viable, either require too much capital or do not have long enough shelf lives to be marketable under current circumstances. Without irrigation, water harvesting systems, or alternatives to groundnut, dry land farmers in Anantapur are highly vulnerable to climate change.

Box 5. Coping options of small and marginal farmers in Jhalawar district, Rajasthan

Jhalawar district in Rajasthan is located in a semi-arid area that receives an average of 943 mm of rainfall annually. In addition to high degrees of climate sensitivity, it also ranks among the districts with the lowest adaptive capacity. Over the past 10 years, many farmers in Jhalawar have shifted from traditional crops, such as sorghum and pearl millet, to soybean, which receives higher market prices and yields quick returns owing to a shorter life cycle. Farmers in Jhalawar are also found to be highly vulnerable to climatic variability. In 2002, Jhalawar experienced its fourth consecutive year of drought, and crop yields were substantially reduced, particularly for the majority of farmers who lack access to irrigation.

Rain-fed agriculture is practised in village Lakhakheri Umat, where 94% of the farmers have small or marginal landholdings. A review of coping mechanisms reveals that a very small group of semi/medium farmers is able to cope with adverse climatic conditions merely through the sale of available stocks (see figure below). On the other end of the spectrum, landless labourers can only resort to seasonal migration due to lack of any productive assets or availability of alternative employment options in the village. Small/marginal farmers use a variety of adaptation options such as sale of cattle, shifts to other crops, labour, as well as seasonal migration. This range of options, however, constitutes only temporary coping measures. Options that enhance longer-term adaptive capacity (such as institutional credit, crop insurance, and use of drought-resistant varieties) are not used by farmers due to procedural complexities and stringent eligibility criteria, compounded by lack of awareness.



Lakhakheri Umat: rainfed farming only
Semi/medium farmers – sale of stocks
Landless labourers – seasonal migration
Small/marginal farmers – temporary coping measures
No long-term adaptive solutions

Anghora: head-end of dam
Access to irrigation opens up range of coping options
Much better availability of electricity, health facilities, and transport infrastructure (Kota markets)
Mixed farming of oranges and soybean

In village Anghora in the same district, however, located at the head-end of the dam, access to irrigation opens up a range of coping options. Farmers in this village cultivate a combination of oranges and soybean for sale in the market. Even small and marginal farmers are able to tide over poor years through use of available stocks and by resorting to credit or loans, and are also better prepared by adopting drought-resistant varieties of crops.

In a recently completed study funded by the World Bank, a methodological framework was sought to be established to quantitatively assess the vulnerability of households to droughts and floods where income was used as a proxy of well being to highlight factors that play a key role in reducing vulnerability. Analysis of primary datasets on coping capacities and income drops during drought, collected from field based surveys were used to suggest suitable interventions to be taken up at the national, state and local levels. Communities who are least resilient to recovery and have a limited capacity to adapt are considered to be highly vulnerable to climate change. Besides locational aspects, there are infrastructural, institutional, socio-economic and political factors that influence adaptive capacities of households. Observed community responses in coping with climate variability have been analysed at a micro level, i.e. at the household level, and at a meso level, i.e. at the community or village level. The determinants of both provide a composite assessment of vulnerability. Case studies carried out indicate that vulnerabilities across communities and households are triggered by many factors including dependence of communities/ households on climate sensitive sources for a living, as well as, access to other safety nets viz., savings, insurance, abilities to diversify cropping patterns, opportunities to diversify income-generating activities and infrastructure built including irrigation and communication facilities (TERI 2007).

The section below highlights a few examples of adapting to existing climate stresses. Natural resource management, buttressing food security, development of social and human capital and strengthening of institutional systems are found to be the most commonly resorted measures that are employed (Adger et al., 2003) that have the potential to enhance adaptive capacities. Such processes, besides building the resilience of communities, regions and countries to shocks and stresses due to climate variability and change are good development practice in themselves.

3.1 Social networks

Social networks and community based systems play a major role for coping with climate stresses, especially given the paucity of formal credit or insurance services in rural areas. Rural households respond to climate stress by turning to moneylenders, selling assets, reducing inputs in farming, or diversifying their activities. Another strategy is to send family members to work elsewhere and remit payments. While such risk management strategies reduce vulnerability in the short term, they can increase vulnerability over the longer term by promoting sub-optimal asset allocation. For instance, small farmers may opt for multiple cropping to reduce income variability rather than risk growing the most profitable crops. Such traditional risk-sharing strategies also break down when disasters affect an entire community or area. For instance, the supercyclone of 1999 badly affected Jagatsingpur district of Orissa. One of the villages in this district, Sunadiakandha, which is located close to the main coast, has experienced increasing salinity and dwindling agricultural productivity. This reflects in the low average incomes in the village, across all land categories. Many people have migrated elsewhere in this village in pursuit of alternate employment, as there is no opportunity in the village after heavy damage from the cyclone. This is seen in the income profile, where almost 20% of the income is received from remittances.

Box 6. Social networks in Bangladesh and India

In village Khonchapara in district Gaibandha, Bangladesh, Oxfam and its local partner organization, Samaj Kallyan Sangsthan introduced a new variety of bean and papaya seeds at low cost, which could be harvested after floods when all the paddy crop is destroyed. The new agricultural crop helped farmers tide over the crisis period for food and income. In Bangladesh, it is not just the farming households who suffer losses during floods but also potter, petty traders, and day labourers due to difficulties in transportation, storage and drying. However, voluntary initiatives have been launched to impart skills

for small enterprises like shoe making, weaving, carpentry, etc. In Gujarat, India, the Self Employed Women's Association (SEWA) successfully used the government's drought relief fund as a revolving fund for investing in women artisans who could embroider during the drought season and sell the product through SEWA cooperatives. The fund grew as women repaid the loan from their earnings, and used it as an available capital resource.
Source: Kapoor (2006), UNFCCC (2007)

Being located along the river Devi in Orissa, floods majorly affect Tarasahi every year and the villagers are devoid of timely help and relief, as the village is rendered cut-off from nearby habitations during times of flood. However the villagers have realized the risks involved in investing in cultivation and have engaged themselves in many other activities such as dairy, fishing, construction activities etc. Around 3000 litres of milk is produced in Tarasahi daily and finances from the Self Help Groups (SHGs) have helped the villagers to buy cattle and sell milk in home fed centres within the village. There are 34 SHGs in the village. It was also observed that women have shops in their name (betel shops, grocery shops). Men and women from the Scheduled Caste community are involved in other income generation activities like fishing and wage labor – construction activities.
Source: TERI (2007)

3.2 Community managed resources

However, community management of resources such as irrigation, roads, and forests is being increasingly recognized as the right approach to ensure judicious and equitable use. Examples include participatory irrigation management and water harvesting in Hiwre Bazaar, Maharashtra (Bhadwal 2006), growth of less water intensive crops (TERI 2007) and rural road user groups in Putalibazar municipality, Nepal (Shreshtha 2006). In fact in times of political conflict (often exacerbated by competition over dwindling natural resources), when there is no respect for government property, community managed forests have been seen to perform better (Nagendra 2006). This study looked at Mahananda Wildlife Sanctuary, which is located in a densely populated area, and subject to frequent people-park conflicts. In the presence of Maoist rebels, restrictive governmental guidelines lead to significant conflict. They found that regular monitoring makes a significant difference to preventing over-harvesting, but monitoring conducted by the community leads to lower conflict levels, and can be effective even in conditions of overall conflict. Similarly, in the Spiti area of Himachal Pradesh, which is a cold snowbound desert for half the year, water rights are owned exclusively by descendants of the original settlers of the village. When water is scarce a preferential system of irrigation rights is followed. This actually helps ensure that crops ripen in succession and the demand for labour is spread over the entire harvest season (UNFCCC 2007).

3.3 Diversifying income patterns

Income diversification is extremely important but the opportunities for income diversification are restricted by education, skills, and landholding size. Seasonal migration into non-specialised wage labour is largely undertaken. Besides, livestock rearing in drought affected regions and aquaculture in coastal regions that are flood affected hold prominence as substitutes for income generation. In India case studies carried out at the household level highlight that large farmers and to some extent farmers with medium landholdings are less diversified compared to the small and marginal farmers and landless categories. While it is found that small/ marginal farmers draw their incomes from varied sources helping in the effective distribution of risk, low level of education and appropriate skillsets render them as the lowest earning categories. Other factors complementing diversification of incomes include better connectivity and proximity to a town or city. In case of floods water logged fields are found in some cases to be used as fishing grounds to earn incomes (TERI 2007). In a case study carried out in Bangladesh on coping capacities and diversifying incomes, flood affected communities were found to shift from rearing poultry to care-taking ducks and geese (CARE Bangladesh 2005). In Bangladesh, it is not just the farming households that suffer losses during floods but also the potters, petty traders, and day labourers due to difficulties in transportation, storage and drying. However, voluntary initiatives have been launched to impart skills for small enterprises like shoe making, weaving, carpentry etc (UNFCCC 2007).

Box 7. Income diversification initiatives in Bangladesh

The south-west region of Bangladesh faces problems of water logging caused by the combined effect of siltation of estuary branches, higher river bed levels, reduced sedimentation in flood protected areas, and impeded drainage, exacerbated by heavy rainfall and sea level rise. This adversely affects available agricultural land, impacting food production, soil productivity, and agricultural livelihoods. In Subarnabad village in south-west Bangladesh, the Institute of Development Education for the Advancement of the Landless (IDEAL) is implementing a project called Reducing Vulnerability to Climate Change (RVCC), funded by the Canadian International Development Agency (CIDA) and implemented by CARE Canada through CARE Bangladesh. The initiatives promoted in Subarnabad focus on new livelihood strategies for income and food generation. These include goat, duck, and hen rearing, chicken and crab farming, tree planting, introduction of salt-water tolerant vegetable gardens and handicraft production. IDEAL has also helped raise awareness about climate change, personal hygiene, sanitation, and the construction of latrines and deep tube wells. Villagers are also able to access loans to establish small crab farming enterprises. While these initiatives are still in the early stages, villagers have been able to slowly pay off their loans and have begun to make some profits, and have also encouraged others to venture into these livelihood activities.

As part of the RVCC project, an awareness campaign was also undertaken to educate the communities about climate change, causes, effects and adaptation strategies. The target population included students, teachers, journalists, newspaper editors, and community leaders in south-west Bangladesh. The campaign used radio programmes (such as short dramas, folk songs, and interviews), eco-clubs, and development of school curriculum to raise grassroots awareness about climate change in a non-technical way. A key conclusion from the project was that awareness activities when targeted in areas where a certain project is being undertaken results in better integration and reinforcement of ideas and involving members of the target audience in the development of communication tools could improve the relevance of the materials and messages.

Source: Pouliotte et al (2006), Tutu and Kulsum (2005)

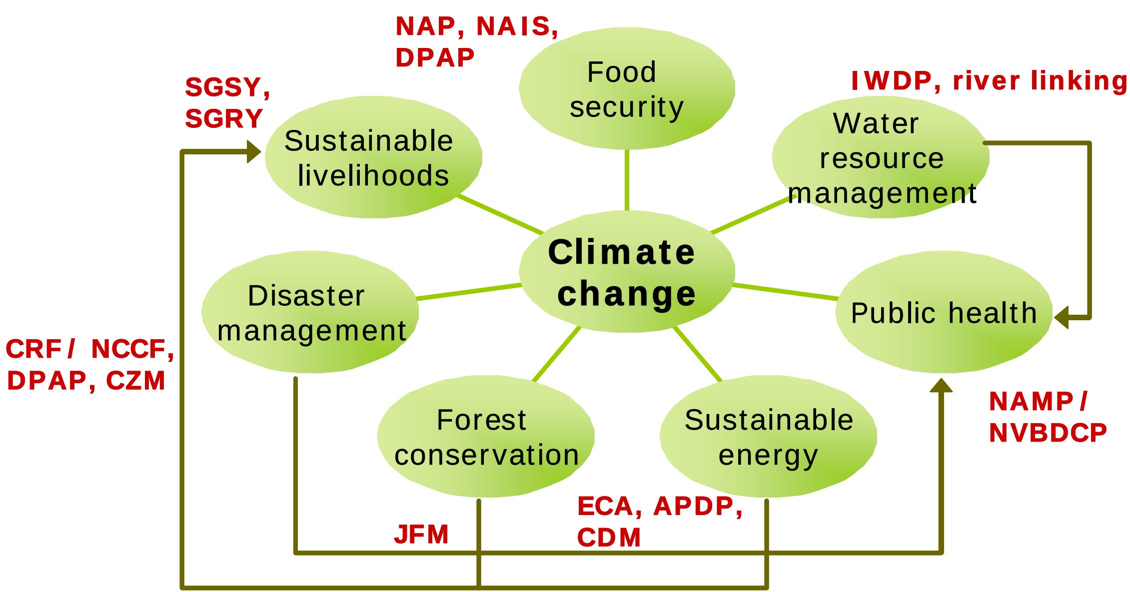
3.4 Traditional "innovations"

Mandarin production in Bhutan is severely affected by long dry spells in the flowering season, to counter which bamboos are used for drip irrigation (as a modified version of polythene pipe drip irrigation). Similarly in northeast India, bamboo pipes are used to divert stream and spring water to irrigate plantations. Other examples are cage aquaculture in household ponds and waterlogged areas in Bangladesh, ploughing fields in the Indian hills in the early morning before dew or fog has evaporated, use of a type of grass ("pang") to line water tanks and irrigation channels to control seepage, and storage of seeds in cowdung in the Andamans (UNFCCC 2007).

4. Strengthening adaptive capacity: strategies in the context of development

Adapting to the changing conditions of climate would form an integral part of sustainable development. Inclusion of climatic risks in the design and implementation of development initiatives is vital to reduce vulnerability and enhance sustainability. A two-fold link can be seen between climate change and development. One, the impacts of climate change can severely hamper development efforts in key sectors. For example, increased threat of natural disasters and growing water stress will have to be factored into infrastructure development including plans for public health infrastructure and coastal infrastructure. Second, development policies and programmes will themselves influence the ability to be able to adapt to the consequences of climate change. For instance, Figure 9 shows that there are important linkages between various sectoral policies in India and the potential impacts of climate change in those and other sectors. Policies for forest conservation and sustainable energy will, if correctly targeted and implemented enhance the resilience of communities and thereby reduce the vulnerability of their livelihoods to climate change.

Figure 9. Climate and development policy linkages for India



NAP - National Agriculture Policy, NAIS - National Agriculture Insurance Scheme, DPAP - Drought Prone Areas Programme
IWDP - Integrated Watershed Development Programme
NAMP - National Anti-Malaria Programme, NVBDCP - National Vector Borne Disease Control Programme
ECA - Electricity Conservation Act, APDP - Accelerated Power Development Programme, CDM - Clean Development Mechanism
JFM - Joint Forest Management
CRF - Calamity Relief Fund, NCCF - National Calamity Contingency Fund, CZM - Coastal Zone Management
SGSY - Sampoorna Grammen Swarozgar Yojana, SGRY - Swarnajayanti Grammeen Rozgar Yojana
TERI (2005)

Developmental efforts can help build adaptive capacity through two levels of interventions:
1. climate-specific interventions such as drought proofing, rainwater harvesting, awareness about available drought-resistant varieties, better access to medium/long-range weather forecasts, and possibly early warning networks.
2. broader capacity building through education, access to agricultural credit, health care infrastructure, etc.

Conversely, however, inappropriate development policies can possibly lead to maladaptation, by ignoring local needs and priorities, existence of multiple stresses, efficiency in resource use, and principles of good governance.

Also, there are various development initiatives carried out by various national and international agencies that if further strengthened fall well in the context of enhancing capacities to address long-term adaptation to climate change. Integrated water resource management is increasingly being regarded as the most effective way to manage water resources in a changing environment with competing demands. Rainwater harvesting and integrated watershed management in rainfed areas would also help increase agricultural resilience to increased climate variability. An integrated approach would entail modifying or extending infrastructure to collect and distribute water, adoption of decentralized rainwater harvesting programmes, and undertaking water pricing initiatives to tame end use demand along with removal of perverse subsidies. At a macro level, policies can seek to improve production and distribution systems to cope with fluctuations in crop yield.

4.1 Case of integrated water resource management in India

In India, integrated watershed development has emerged as an effective approach in augmenting water supply through conservation of rainwater in rainfed farming systems, which account for nearly two-thirds of the country's cultivated land and encompass the arid and semi-arid regions and the drought prone areas. Interventions in dry land/ rain fed regions that are characteristic of poor climate - dry weather and low rainfall conditions and highly eroded soils were primarily targeted under the programme. The IWMP suggests the employment of an integrated and coordinated approach across various ministries to promote soil and water conservation by optimizing land-use production systems and use of sustainable low-cost location specific technologies (MoEF 2001). The watershed approach basically is a project based development plan for water harvesting, water conservation and other related social and economic activities that seek to enhance the production potential of an area on a sustainable basis. There is growing awareness at the central government level that integrated watershed development can also prove a potent instrument of adaptation to climate change. There are special programmes such as Drought Prone Areas Programme (DPAP) for almost one-sixth of the land area in the arid and semi arid regions of the country, in addition to the special programme of watershed treatment in the catchment of river valley projects and flood prone rivers.

The Government of India (GoI) has several plans and programmes to facilitate development of degraded lands to improve conditions in rainfed regions across the country:

- The Drought Prone Area Programme (DPAP) of the GoI is aimed at soil and moisture conservation in drought prone areas. The primary objective is promotion of overall economic development mainstreaming marginalized and vulnerable sections.
- The Desert Development Programme (DDP) was later introduced to restore ecological balance, conservation of soil and water and to arrest the desertification through shelterbelt plantations.
- The Integrated Wasteland Development Programme (IWDP) was introduced with the aim to develop wastelands for overall economic development besides improving economic conditions of resource poor population.
- The National Watershed Development Programme in Rainfed Areas (NWDPRA) initiated in 1990-91 targeted improvement in agricultural production in rainfed areas restoring ecological balance.
- In order to channelise greater resources for rainfed areas, National Bank for Agriculture and Rural Development (NABARD) set up a Watershed Development Fund of Rs 2 billion in the year 2000-2001.
- Apart from these, the River Valley Project, Flood Prone River programme, the watershed development project for shifting cultivation Areas (WDPSCA) were introduced to check siltation of reservoirs and enhance productivity of degraded lands.

Institutions both governmental and non-governmental play important roles in providing a thrust to these programmes. Panchayati Raj Institutions (PRIs) and Non Governmental Organisations (NGOs) have an active role to play in the implementation component of most of these programmes.

Box 8. Example of watershed management in India

Lakkenahally micro-watershed covers 210 acres divided by ravines into three micro-catchments. This land was owned by 62 families and was vulnerable to floods. Crops were often washed away, and many fields had not been cultivated for several years.

In 1991, three Credit Management Groups (CMG) were formed with a total membership of 54. A Watershed Development Association (WDA) was also established in 1992. One of the CMGs was a women's group with 14 members. These were small, homogenous, voluntary, and autonomous groups that mobilized savings. They developed their own rules and regulations governing the purpose and size of loans, interest rates, schedules of recovery, and sanctions. They provided credit and group support to help their members meet their livelihood needs, e.g. by providing loans for various forms of consumption, small business and cottage industries.

The main problems faced by farmers were erratic rainfall, low moisture holding capacity of soils, and declining productivity. As part of a collective exercise, 75 farmers (including 35 women) outlined a plan of action, and agreed on the contribution towards the costs of the activities. The following activities were taken up on a priority basis:

1. Construction of silt traps to build up adequate soil in areas with high water storage potential. The improved water holding capacity would reduce the risk of crop failure in these areas. Farmers who cultivate lands in the tank bed downstream would also benefit in terms of reduced damage by floods rushing through the ravine.
2. Excavation of small open wells near reclaimed areas. This provided farmers with protective irrigation, and they were able to introduce a paddy crop.
3. Wasteland development was taken up on 16 acres of land. This included regeneration of a hillock, with farmers working at lower wages to construct protection walls and plant saplings around the hillock. The grasses were harvested and sold locally by the credit group, indicating the sustainability of the exercise.

Hence, this approach combines different categories of adaptation options viz. prevention and modification of impacts and events, and changes in use.
Source: Fernandez (1993)

4.2 Mainstreaming of climate change concerns

The ongoing programmes of the Government of India to promote sustainable agriculture, forestry and coastal zone regulation include

- Drought and Flood proofing measures
- Zero-tillage practices
- Development of drought resistant varieties and salt tolerant varieties
- Promoting on-farm water management practices and promotion of water conserving technologies
- Kissan Credit Scheme
- Promoting crop diversification
- Insurance
- Integrated Watershed Management Programme
- Coastal Zone Management Plan
- Joint Forestry Management Programme

The Government of India has been trying to mainstream sustainable development concerns into relevant sector policies. **Several ongoing efforts address some of these vulnerability concerns, although they are primarily driven by the objective of sustainable livelihoods and poverty alleviation** (GoI 2006). While certain ministries like the Ministry of Agriculture, Ministry of Water Resources, and Ministry of Environment and Forests are conscious of the role that such policies and programmes can play in strengthening adaptive capacity, **they do not as yet explicitly incorporate the *increased* risks (of temperature rise, drought or flooding) due to climate change.**

Recent initiatives by the Department for International Development (DFID) and the World Bank in India seek to identify how to integrate adaptation and risk reduction into their portfolio of programmes. The ORCHID project: DFID-India Climate Risk Screening Process aims to compile sub-national vulnerability indicators for current and future climate change, carry out risk assessment of high priority DFID India interventions, and develop potential adaptation and risk reduction measures. The interventions being assessed are the following.

- National Rural Water and Sanitation Programme
- National Elementary Education Programme (Sarva Shiksa Abhiyan)
- National Reproductive and Child Health Programme Phase II
- Kolkata Urban Services for the Poor
- West Bengal Support to Rural Decentralisation
- West Bengal Health Systems Development Initiative
- Andhra Pradesh Rural Livelihoods Programme
- Madhya Pradesh Rural Livelihoods Programme
- Madhya Pradesh Urban Services for the Poor, and Western Orissa Rural Livelihoods Project.

The World Bank project "Addressing Vulnerability to Climate Variability and Climate Change through an Assessment of Adaptation Issues and Options" has the overarching goals of enhancing the consideration of climate and climate-related issues in India's development process, and achieving a more effective integration and mainstreaming of climate issues in the Bank's project preparation and appraisal processes. Activities include

- identification of policies, measures and practices that might be modified to reduce vulnerabilities
- analysis of appropriate institutional and participatory mechanisms to merge current community driven development priorities with the need to address wider environmental externalities such as adaptation to climate change
- assessment of the climate-related risks associated with a subset of Bank operations in India.

Other relevant programmes in South Asian countries include the Village Aid Programme and the Integrated Rural Development Programme (IRDP) facilitating digging canals, increasing connectivity and adaptation of improved farm practices in Pakistan; the IRDP and the Minimum Needs Programme for infrastructure development and programmes on watershed management and on capacity building in India; Grameen Bank programme for rural credit to rural poor (Box 9) and the Bangladesh Rural Advancement Committee on providing education and training in Bangladesh and irrigation projects in Sri Lanka.

Box 9. Grameen Bank operations in Bangladesh

The Grameen Bank provides small loans, issued without formal collateral, which enable the poor to set up small income-generating businesses and climb out of poverty. In 1984 the Bank began lending money for housing loans. The housing loans are available only to existing Grameen Bank borrowers who have a 100% repayment record and have completely repaid their first two loans for income generation activities. The Grameen Bank has developed two standard house designs. In cases of severe flooding the house can be dismantled and the components stored and reassembled later. Loans are also available to purchase land if a family has no land on which to build its house. The title to the house is vested with the borrower, and in 96% of the cases this is the woman. The borrowers repay their loans on a weekly basis and the collateral system of peer support means that families help each other out with payments if necessary. 617,000 houses have been built using these loans.
Source: UNFCCC (2007)

In Bangladesh, ongoing projects intend to address food insecurity and food production shortfalls by crop diversification and generation of other employment opportunities aiming at community development, agricultural development, credit facilities, and infrastructure improvement. Fish and shrimp production for domestic consumption and exports are promoted with special emphasis on rural poverty alleviation & employment generation. This is done by improving the capacity of local users to manage aquatic resources in a sustainable and equitable way thereby conserving aquatic biodiversity. All these developmental programmes play an important role in enhancing the resilience of the poor. Rain water harvesting and integrated development of watersheds in rainfed areas help in increasing agricultural resilience to erratic weather events under a climate change scenario. Additionally, at a more macro level, policies and plans can seek to improve production and distribution systems to cope with fluctuations in crop yield. New technologies and practices are more readily acceptable to farming communities if well ingrained in the indigenous system. Therefore modified traditional methods for conservation of natural resources could be adopted to cope with these changes.

Bangladesh has its own Participatory Disaster Management Programme (PDMP) with the focus towards disaster management and prevention, and also adaptation to climate change. There is no national policy in place yet to comprehensively address climate change risks. The disaster management project mainly focuses on soft measures to reduce the impact of disasters in Bangladesh. In particular, it aims to increase awareness on practical ways to reduce disaster risks and losses, to strengthen national capacity for disaster management (with emphasis on preparedness), enhance knowledge and skills of key personnel in handling disasters, establishing disaster action plans in the most disaster prone areas promoting local–level risk reduction measures, and improving early warning systems.

The UNDP Comprehensive Disaster Management Programme (CDMP) aims to establish a systematic approach to prediction, monitoring, protection, evacuation, land use zoning, and information dissemination to build adaptive capacity, which in turn requires comprehensive and appropriate information produced and delivered at the right time, to the right people and agencies. Bangladesh's interim poverty reduction strategy paper (I-PRSP) recognizes the direct links between poverty and vulnerability to natural hazards. It notes that the incidence of disasters is likely to increase rather than decrease particularly due to the impacts of global warming. Climate change so far is not mentioned in the context of planning vulnerability reduction measures.

Box 10. Need to mainstream climate change adaptation measures in Bangladesh Sunderbans

The Bangladesh Sunderbans support close to a million people, whose lifestyles are well adapted to tidal and seasonal variations in water and salinity levels. For instance, dwellings are built on raised platforms, farmers cultivate flood-tolerant rice during the monsoon, and harvest salt-tolerant fish during the dry season. These traditional livelihoods however, are under pressure from rapid population growth, poaching of wildlife, increased felling of timber due to growing industrial demand, and shrimp farming which boomed as a major export industry in the mid-1980s. The impact of climate change on the Sunderbans will constitute an additional stress. Adaptation measures need to be mainstreamed into a wider system of response to the climatic and non-climatic pressures on the ecosystem.
Source: Agrawala S (2005)

A note of caution must be sounded when we speak of mainstreaming climate change into development policy. It is not always necessary that the two are in agreement, or even that climate change policies are internally consistent. For instance, planning for reduced streamflow due to climate change may necessitate the building of storage reservoirs rather than run of the river projects in mountainous areas. However, the increased risk of GLOFs would indicate the contrary (Agrawala 2005). Similarly, development through income diversification may take the form of encouragement of tourism, horticultural production, mining, etc at the expense of fragile mountain resources (Jodha 1995). Highly rigid engineering type interventions may actually lock a system or community into an inflexible pattern of production and make them more vulnerable to climate change over time. Given the complexity and inter-connectedness of social, economic, and ecological systems, adaptation interventions that address only a part of the system may not have the desired impact, and may even be maladaptive. Moench et al (2003) argue that 'when situations are characterized by variability, uncertainty, and change, conventional planning scenarios provide little guidance regarding future needs and conditions.' For adaptation, 'specific solutions are less important than the existence of processes and frameworks that enable solutions to be identified and implemented as specific constraints and contexts change'. TERI and IISD (2006) are exploring the idea of "adaptive policies", i.e. policies that themselves respond to changes in underlying conditions, either through in-built trigger mechanisms or through formal processes of feedback and learning. Through this approach institutions and policies could be designed to enhance the resilience of communities and their overall ability to respond to change.

However, there are numerous win-win options which can help integrate vulnerability reduction into development, such as:

- introduction of drought-tolerant and salt-tolerant crop varieties
- siting of hydropower facilities in low risk locations
- early warning systems
- construction of embankments and appropriate housing in flood-prone areas
- application of information and communication technologies in rural areas

4.3 Role of government and other stakeholders

In Bangladesh, ongoing projects address food insecurity and food production shortfalls by crop diversification and generation of other employment opportunities aiming at community development, agricultural development, credit facilities, and infrastructure improvement. Fish and shrimp production for domestic consumption and exports are promoted with special emphasis on rural poverty alleviation and employment generation. This is done by improving the capacity of local users to manage aquatic resources in a sustainable and equitable way thereby conserving aquatic biodiversity. All these developmental programmes play an important role in enhancing the resilience of the poor. Adaptation often requires a chain of services that only the government can provide. For instance, high value crops like medicinal plants and vegetables can be grown by farmers to diversify their incomes, but these need markets, storage, and transport facilities that require government intervention.

However, there are important roles that can be played not just by the government but by the private sector and by voluntary agencies. Farmers in Chitradurga in south India are being encouraged through state government and private initiatives to cultivate alternative crops, such as areca nut, pomegranate, and banana for income diversification. Over the last five years, export companies have increasingly entered into buy-back contracts with farmers for gherkin production aimed at European markets, with plans to expand to other vegetables. Interestingly, due to the economics of gherkin cultivation, it is the small and marginal farmers with small landholdings and family labour that are most able to benefit from such contract farming. Kisan kendras (farmer centres) set up by corporates also provide scientific soil testing services, market information, and transport facilities to cultivators of horticultural crops, in return for a subscription fee. In Raipur in central India, fragrant varieties of rice were traditionally grown in the southern part of the district and commanded high economic value. But adulteration at the merchant level has reduced the prices for these varieties over the last 10 years. In a bid to increase yields, farmers have started replacing organic manure with chemical fertilizers, but this has made the crop highly vulnerable to pests and diseases. Local NGOs are playing an important role in conserving indigenous varieties of seeds in the region by setting up village-level seed banks that are also useful in the event of drought and crop failure.

Similarly there is a potential role for public-private partnerships in the provision of financial services in rural areas. Village case studies in Orissa highlight that many households are in a debt trap. Loans are taken to cope with droughts and floods from private money lenders at high rates of interest. Formal credit is not used due to lack of information, lack of trust, complex procedures, and lack of assets for collateral. When loans are taken for agriculture and the crops are washed away during floods, households are unable to repay the loan and continue to face high rates of interest, further spiralling them into poverty (TERI 2007). Experience with microfinance in recent years has shown that the poor are bankable, although there are considerable challenges of scale and profitability. Similarly, there is increasing discussion of microinsurance schemes, which are backstopped by public or donor funding in the event of natural disasters.

Box 11. Weather-indexed insurance for agriculture

The recent liberalization of the Indian insurance market has opened the door for foreign and private players who have introduced innovative products in search for new markets. These include index-based weather risk insurance contracts which have emerged as an alternative to traditional crop insurance. These are linked to the underlying weather risk defined as an index based on historical data (e.g. for rainfall, temperature, snow, etc) rather than the extent of loss (e.g. crop yield loss). As the index is objectively measured and is the same for all farmers, the problem of moral hazard is minimized, the need to draw up and monitor individual contracts is avoided, and the administration costs are reduced. Weather-indexed insurance can help farmers avoid major downfalls in their overall income due to adverse weather related events. This improves their risk profile and enhances access to bank credit, and hence reduces their overall vulnerability to climate variability. Unlike traditional crop insurance where claim settlement may take up to a year, quick payouts in private weather insurance contracts can improve recovery times and thus enhance farmers' coping capacity. Although the lead was taken by private sector entrants, in 2005, the public sector AIC also launched an indexed insurance scheme for deficit rainfall across 10 states. AIC could draw on its established network to sell insurance to more than 125,000 farmers growing crops over 98,000 hectares, covering a risk of approx Rs 560 million, earning a premium of Rs 32 million. Claims were processed in a month from the close of indemnity period. Compensation of Rs 1.2 million was paid to nearly 300 farmers in two stations in Uttar Pradesh.
Source: TERI and IISD (2006)

Few community level initiatives exist that are localized and driven by local leadership, e.g. Hiwre Bazaar and Ralegaon Siddhi in Maharashtra and Tarun Bharat Sangh in Rajasthan. Hiwre Bazaar in Ahmednagar district, Maharashtra state, India lies in a drought prone region, but many villages had not been covered under the Government of India's Drought Prone Area Programme 15 years ago. Yet the major crop grown was highly water-intensive sugarcane, due to ready demand from sugar mills in the state. However, the result was dramatically falling water tables and reduced availability of drinking water. In this situation, the village headman took the lead in introducing soil conservation and groundwater recharge measures in the village with support from a small number of people. Not only were these activities successful in raising water levels, the community also shifted to a less water-intensive cropping pattern of maize and onions. This case highlights how strong leadership can transform the resilience of a community to cope with drought (Bhadwal 2006). The Tarun Bharat Sangh has helped villagers in Rajasthan with watershed management by reviving water harvesting traditions such as check dams and tanks. The organization has helped establish 3000 water harvesting structures in 650 villagers of Alwar district (TBS website).

Such initiatives need to be scaled up, which is only possible if we understand the processes behind the success stories, and use them as testimonials for replication elsewhere. The government is a key stakeholder in this process as it has the resources and policy instruments to scale up best practices. However, institutional factors, power relations, and social hierarchy play critical roles in allowing or hindering access to adaptation measures. A key factor therefore is empowerment at the grassroots level, through strengthening of self help groups and local governance structures. Community driven initiatives can work with government or planned initiatives – the need is on the one hand for policy to provide incentives to encourage communities to use natural resources more judiciously, and on the other hand, to integrate and replicate good practices.

Micro studies in Orissa (TERI 2007) showed that households living in flood prone areas feel that the most significant schemes of the government are the housing scheme, Indira Awas Yojana, the Food for Work Programme, and the rural road building scheme, Pradhan Mantri Grameen Sadak Yojana. These schemes have provided relief in the aftermath of floods and cyclones, enabled recovery and rebuilding, and helped improve connectivity selling produce and finding alternative employment. The key message is that government policies, public-private partnerships, corporate and voluntary initiatives all can be meaningfully harnessed to build resilience to climate change.

5. Conclusions

Various studies summarized in this paper show that climate change is a grave and immediate issue for South Asia. The impacts of climate change on food security, access to water, human health, ecosystems, urban areas, and frequency of disasters will have severe implications for the achievement of sustainable development. Present coping capacity is very limited particularly for small farmers, rural communities eking out precarious livelihoods dependent on natural resources, urban poor living in marginalised conditions, women and children. There are several good practices and policies, some of which are showcased above, but these need to be scaled up. While government programmes in these sectors address issues relevant for strengthening adaptive capacity to climate change, they do not as yet explicitly incorporate the increased risks due to climate change.

Forums like the South Asian Association for Regional Cooperation (SAARC), Bay of Bengal Initiative for Multi-Sectoral Technical and Economic Cooperation (BIMSTEC) and South Asia Cooperative Environment Programme (SACEP) promote regional cooperation to address some of these issues. Besides, there are major bilateral and multilateral initiatives taken forward by the World Bank, the Department for International Development, the International Development Research Centre and the Asian Development Bank. One of the three pillars of the World Bank Investment Framework seeks to focus on supporting adaptation to climate change. An adaptation work plan has been outlaid with components relating to screening public investments, adapting existing capital stocks, developing best practice standards, promoting disaster preparedness, developing a research programme with agriculture and water resource as focus areas, finding ways to support incremental costs to promote adaptation in vulnerable regions and conducting country specific studies. The Nairobi Framework on Impacts, Vulnerability and Adaptation shall assist all countries, in particular developing countries, including the least developed countries and small island developing states to improve their understanding on impact, vulnerability and adaptation issues to be able to make informed decisions on practical adaptation actions and measures to respond to climate change.

However, a sustained movement at a localised scale is required to facilitate meeting the basic needs of many who are deprived of access to food, safe drinking water and sanitation and shelter requirements. A holistic approach which addresses issues of natural resource management, sustainable livelihoods, and climate change adaptation requires development of a stronger knowledge base at various levels (local, national and global) for enhanced understanding of ecosystem functions and capacity, valuation and internalisation of value of ecosystem services, and stakeholder engagement in ecosystems management.

Annex. Summary of climate change vulnerability and impacts in South Asian countries

Country	**Vulnerability to Climate Change**
Bangladesh	**Water Resources** Water related impacts of climate change likely to be most critical– largely related to coastal and riverine flooding, but also enhanced possibility of winter (dry season) drought in certain areas. Both *coastal* flooding (from sea and river water), and inland flooding (river/rain water) are expected to increase. **Coastal zones** Acute impacts on coastal zones due to the combined effects of climate change, sea level rise, subsidence and changes of upstream discharge, cyclones and coastal embankments. Four key types of primary physical effects i.e. saline water intrusion, drainage congestion, extreme events, changes in coastal morphology identified as key vulnerabilities in the coastal areas. **Agriculture** The estimated impacts on rice yield shall vary between -6% to +14% depending on different climate change scenarios (Rosenzweig and Iglesias 1994 and Matthews et al 1994) Agricultural areas in tropical Asia and Bangladesh in particular, are vulnerable to many environmental extremes such as floods, cyclones, and storm surges. For example, on an average during the period 1962-1988, Bangladesh lost about 0.5 million tones 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)..
Bhutan	**Water Resources** The availability of water in Bhutan is heavily dependent on heavy rainfall, glaciers or snow, land use practices, and user demand. A reduction in the average flow of snow-fed rivers, combined with an increase in peak flows and sediment yield, would have major impacts on hydropower generation, urban water supply, and agriculture. An increase in rainfall intensity may increase run-off, enhance soil erosion, and accelerate sedimentation in the existing water supplies or reservoirs. **Agriculture** In Bhutan upland crop production, practiced close to the margins of viable production, can be highly sensitive to variations in climate. A temperature increase of 2 °C would shift the cultivating zone further into higher elevation. Climate change is expected to increase the severity and frequency of monsoonal storms and flooding in the Himalayas, which could aggravate the occurrence of landslides. In addition to the danger to life and property, some of the generated sediments may be deposited in the agricultural lands or in irrigation canals and streams, which will contribute to deterioration in crop production and in the quality of agricultural lands (NEC 2000). **Extreme events** In Bhutan, the entire northern upper land has glacier/snow-fed lakes in the mountaintops. Increased temperature and greater seasonal variability in precipitation will lead to accelerated recession of glaciers and result in increase in the volume of these lakes (IPCC 1998).
India	**Agriculture** Among the cereals, wheat production potential in the sub-tropics is expected to be affected the most, with significant declines anticipated in several regions including South Asia (IIASA, 2002). For eg., wheat yields in central India may drop by 2% in a pessimistic climate change scenario (GoI 2004). Districts in western Rajasthan, southern Gujarat, Madhya Pradesh, Maharashtra, northern Karnataka, northern Andhra Pradesh, and southern Bihar are highly vulnerable to climate change in the context of economic globalization. Numerous physical (e.g. cropping patterns, crop diversification, and shifts to drought-/salt-resistant varieties) and socio-economic (e.g. ownership of assets, access to services, and infrastructural support) factors come into play in enhancing or constraining the current capacity of farmers to cope with adverse changes (TERI 2003) Temperature rise of 1.5 degree centigrade and 2 mm increase in precipitation could result in a decline in rice yields by 3 to 15 %. Sorghum yields would be affected and yields are predicted to vary from +18 to -22 % depending on a rise of 2 to 4 degree centigrade in temperatures and increase by 20 to 40 % of precipitation. (IPCC 2001). **Water resources** Increased glacial melt due to warming is predicted to affect river flows. Increased warming might result in increased flows initially with reduced flows later as the glacier disappears. Available records suggest that Gangotri glacier is retreating by about 30 m yr-1. A warming is likely to increase melting far more rapidly than accumulation. As reported in IPCC (1998), glacial melt is expected to increase under changed climate conditions, which would lead to increased summer flows in glacier fed river systems for a few decades, followed by a reduction in flow as the glaciers disappear. Climate change could impact the Indus River basin. The total annual run-off from the upper basin is likely to increase by 11% to 16%. It estimated that although increased run-off could be advantageous for water supply and hydropower production it could aggravate problems of flooding, waterlogging, and salinity in the upper basin. Also, even with an overall water surplus, shortages might occur in local areas of the highly productive Punjab rice–wheat zone and in the unglaciated valleys of the upper basin. According to United Nations projections, India is estimated to experience water stress by 2025, and is likely to cross the 'water scarce' benchmark by the year 2050 under the high growth scenario. Water stress and scarcity are defined as situations where per capita annual water availability is less than 1700 m3 and 1000 m3 respectively.

	Human Health Changes in climate may alter the distribution of important vector species (for example, mosquitoes) and may increase the spread of disease to new areas that lack a strong public health infrastructure. High altitude populations that fall outside areas of stable endemic malaria transmission may be particularly vulnerable to increases in malaria, due to climate warming. The seasonal transmission and distribution of many other diseases transmitted by mosquitoes (dengue, yellow fever) and by ticks (Lyme disease, tick-borne encephalitis), may also be affected by climate change (GoI 2004).
Maldives	**Water Resources** 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). **Ecosystem and Biodiversity** Studies show that the corals are very sensitive to changes in sea surface temperature. Unusually high sea surface temperatures in 1998 had caused mass bleaching on coral reefs in the central regions of the Maldives. If the observed global temperature trend continues, there would be a threat to the survival of the coral reefs in the Maldives (Ministry of Environment and Construction 2005). **Extreme Events** Over 80% of the land area in the Maldives is less than 1 m above mean sea level. Being so low-lying, the islands of the Maldives are very vulnerable to inundation and beach erosion. Presently, 50% of all inhabited islands and 45% of tourist resorts face varying degrees of beach erosion. Coastal infrastructure is also highly vulnerable to the impacts of sea level rise and extreme events. Given the geophysical characteristics of the islands and the population pressure, all human settlements, industry and vital infrastructure lie close to the shoreline. **Human Health** Although malaria has been eradicated from the Maldives, climate change is likely to induce a threat of malaria outbreaks. Poor sanitation in the islands of Maldives alongwith conducive environment for the spread of diseases might lead to the outbreak of water related and waterborne diseases such as diarrhoea (Ministry of Environment and Construction 2005).
Nepal	**Water Resources** Studies reported in Nepal's initial national communication indicate no major changes in the hydrological behaviour due to rise in temperatures. However, changes in precipitation are expected to have major impacts. es in Nepal are categorised as dangerous due to threat to glacier lake outburst floods (GLOFs) (WWF 2005). As highlighted by IPCC (2001), glacial melt is expected to increase under changed climate conditions, which would lead to increased summer flows in some river systems for a few decades, followed by a reduction in flow as the glaciers disappear. **Agriculture** Soil loss is a major cause of decline in agriculture production in Nepal and the negative effects of climate change may further aggravate this situation. The impact of rise in temperatures on wheat and maize are expected to be negative. **Extreme Events** In Nepal, DHM (2004) found that almost 20% of the present glaciated area above 5000 m altitude is likely to be snow and glacier free with an increase of air temperature by 1° C. Similarly, a rise in 3° C and 4° C temperatures would result in the loss of 58 to 70 % of snow and glaciated areas with threat of GLOFs. **Human Health** Studies carried out in Nepal indicate the risk of malaria, kalaazar and Japanese encephalitis under different climate change scenarios. The subtropical and warm temperate regions are predicted to be particularly vulnerable to malaria and kalaazar.
Pakistan	**Agriculture** In the hot climate of Pakistan, cereal crops are already at the margin of stress. An increase of 2.5oC 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. The flow of Indus river basin is also likely to effect the cotton production in Pakistan, which might be detrimental to the economy as it is the main cash crop of the country. **Extreme Events** Pakistan comparatively is less vulnerable to changes in sea level but for the port city of Karachi. Karachi's greatest vulnerability to climate change may come from increased monsoonal and tidal activity, resulting in periodic flooding.

Sri Lanka	**Water Resources** Studies indicate that much of the water from heavy rainfall events in Sri Lanka would be lost as run-off to the sea. **Agriculture** Extreme events of rise in temperature and changes in rainfall patterns will have adverse impacts on agricultural production in Sri Lanka. Most cropping activities for e.g., coarse grain, legumes, vegetables, and potato are likely to be affected adversely due to the impacts of climate change. The highest negative impact is estimated for coarse grains and coconut production. 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 meters (Wijeratne 1996). With the tea industry in Sri Lanka being a major source of foreign exchange and a significant source of income for labourers the impacts are likely to be grave. **Extreme Events** Significant erosion is already evident on many of Sri Lanka's beaches. This is likely to increase significantly with accelerated sea level rise. A rise in sea level would tend to cause a shoreline recession except where this trend is balanced by the influx of sediment. In a 30 cm sea level rise scenario, the study projects a possible shoreline recession of about 30 m and for a 100 cm scenario, the shoreline retreat is expected to be about 100 m. A one metre rise in sea level could drown most of the coastal wetlands in Sri Lanka. **Human Health** In Sri Lanka, expansion and shift in malarial transmission zones is expected. Areas bordering the non-endemic wet zone of the country are likely to become highly vulnerable to malaria (MENR 2000).

References

Agrawala S. 2005. Bridge over troubled waters: linking climate change and development. Paris: Organisation for Economic Cooperation and Development. 153 pp.

AfDB (African Development Bank) et al. 2002. Poverty and climate change: reducing the vulnerability of the poor. A contribution to the Eighth Conference of the Parties to the United Nations Framework Convention on Climate Change.

Bhadwal S. 2006. Community initiatives in enhancing resilience to cope with climatic variability and extreme weather: a case study in Maharashtra. Proceedings of the International Conference on Adaptation to Climate Variability and Change, 5-7 January 2006, New Delhi, organized by Institute for Social and Environmental Transition, and Winrock International India. 184 pp.

DHM (Department of Hydrology and Meteorology). 2004. Initial national communication of Nepal under the United Nations Framework Convention on Climate Change. Kathmandu: DHM. http://unfccc.int/resource/docs/natc/nepnc1.pdf

D'Souza M. 2006. Impact of water and food security on human health in the mining regions of Goa. Paper presented in the International Conference on Energy, Environment, and Development: Analysing Opportunities for Reducing Poverty, organized by TERI (The Energy and Resources Institute), Institut Veolia Environnement, and Institut du Développement Durable et des Relations Internationales, 14-16 December 2006, Bangalore, India.

Fernandez A P. 1993. The Myrada experience: The interventions of a voluntary agency in the emergence and growth of people's institutions for sustained and equitable management of micro-watersheds. Bangalore: Myrada. 90 pp.

UNEP (United Nations Environment Programme), 2003. GEO Year Book 2003. Nairobi: UNEP.

UNEP (United Nations Environment Programme). 2007. GEO yearbook 2007: An overview of our changing environment. Nairobi: UNEP. 86 pp.

GoI (Government of India). 2004. India's initial national communication to the United Nations Framework Convention on Climate Change. New Delhi: Ministry of Environment and Forests, GoI. 266 pp.

GoI (Government of India). 2006. Energy for the future: making development sustainable. New Delhi: Ministry of Environment and Forests, GoI and TERI Press.

Haq K et al. 2003. Human development in South Asia 2002: Agriculture and rural development. Oxford: Oxford University Press. 242 pp.

Haritashya U K, Bishop M P, Shroder J F, Bulley H N N, and Olsenholler J A. 2006. Glacier fluctuations and downwasting in the Hindukush and Karakoram Himalayas. 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.

IPCC (Intergovernmental Panel on Climate Change). 1998. The regional impacts of climate change: an assessment of vulnerability . Cambridge: Cambridge University Press.

IPCC (Intergovernmental Panel on Climate Change). 2001. Climate change 2001: impacts, adaptation and vulnerability. Cambridge: Cambridge University Press.

IRI (International Research Institute for Climate Prediction). 2005. Sustainable development in Africa: is the climate right? IRI technical report no. IRI-TR/05/1. New York: IRI, The Earth Institute at Columbia University. 43 pp.

Islam S and Rehman N. 2006. Future change in the frequency of warm and cold spells durations over Pakistan simulated by the PRECIS regional climate 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.

Jodha N S. 1995. The Nepal middle mountains. In Kasperson J X, Kasperson R E, and Turner B L. Regions at risk: comparisons of threatened environments. Tokyo: United Nations University Press. Pp. 140-185. Cited in UNDP. 2005. Adaptation policy frameworks for climate change: developing strategies, policies, and measures. Cambridge: Cambridge University Press. 258 pp.

Kapoor A. 2006. Mitigating natural disasters through preparedness measures. Proceedings of the International Conference on Adaptation to Climate Variability and Change, 5-7 January 2006, New Delhi, organized by Institute for Social and Environmental Transition, and Winrock International India. 184 pp.

Karim, Hussain, and Ahmed. 1996. Assessing impacts of climate variations on foodgrain production in Bangladesh. In Erda L et al. (eds) Climate change variability and adaptation in Asia and the Pacific. Dordrecht, The Netherlands: Kluwer Academic Publishers.

Kelkar U, Narula K K, Sharma V P, and Chandna U. 2006. Coping with climate variability and water stress in Uttaranchal state, India. 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.

Kumar K S K and Parikh J. 2001. Indian agriculture and climate sensitivity. Global Environmental Change 11(2): 147-154.

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

Mirza M Q M. 2002. Global warming and changes in the probability of occurrence of floods in Bangladesh and implications. Global Environmental Change12(2):127-138.

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

MoEF (Ministry of Environment and Forests). 2001. India: National Action Programme to Combat Desertification. Volume - I: Status of Desertification. Government of India, New Delhi.

Moench M, Dixit A, Janakarajan S, Rathore M S, and Mudrakartha S. 2003. The Fluid Mosaic: water governance in the context of variability, uncertainty, and change [Synthesis paper]. Nepal Water Conservation Foundation, Kathmandu, Nepal and the Institute for Social and Environmental Transition, Boulder, Colorado, USA

Nabarro D, Cassels C, and Pant M. 1990. Coping strategies of households in the hills of Nepal: can development initiatives help? IDS Bulletin 20(2): 68-74. Cited in UNDP. 2005. Adaptation policy frameworks for climate change: developing strategies, policies, and measures. Cambridge: Cambridge University Press. 258 pp.

Nagendra H. 2006. The human dimensions of forest change: observations from the air and on the ground. Paper presented in the International Conference on Energy, Environment, and Development: Analysing Opportunities for Reducing Poverty, 14-16 December 2006, in Bangalore, India, organized by TERI (The Energy and Resources Institute), Institut Veolia Environnement, and Institut du Développement Durable et des Relations Internationales.

NEC (National Environment Commission). 2000. Initial national communication under the United Nations Framework Convention on Climate Change. Thimphu: NEC, Royal Government of Bhutan. http://unfccc.int/resource/docs/natc/bhunc1.pdf

Noronha L, Choudhri B S, and Nairy K S. 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. New Delhi: TERI. Pp 121-142.

O'Brien K, Leichenko R, Kelkar U, Venema H, Aandahl G, Tompkins H, Javed A, Bhadwal S, Barg S, Nygaard L, West J. 2004. Mapping vulnerability to multiple stressors: Climate change and globalization in India. Global Environmental Change 14(4): 303-313.

Paul V, Singh T P, and Das A. 2003. Potential impact of climate change on forests: a case study in Uttaranchal. In TERI. 2003. Environmental threats, vulnerability and adaptation: case studies from India. New Delhi: TERI. Pp 197-225.

Paul and Rashid. 1993. Flood damage to rice crop in Bangladesh. The Geographical Review 83(2): 151-159.

Pouliotte J, Islam N, Smit B, and Islam S. 2006. Livelihoods in rural Bangladesh. Tiempo 59: 18-22.

Raut A. 2006. Climate impacts on Nepal. Tiempo 60: 3-5.

Shreshtha A. 2006. Role of Community and Informal Systems in Reducing Vulnerability to Weather Related Disasters: A case study in Putalibazaar Municipality, Nepal. Report to START (the global change SysTem for Analysis, Research and Training).

Shrestha K L, Shrestha M L, Shakya N M, Ghimire M L, and Sapkota B K. 2003. Climate change and water resources of Nepal. In Muhammed A (ed). Climate change and water resources in South Asia. Kathmandu: Asianics Agro Dev International. 259 pp.

Somaratne S and Dhanapala A H. 1996. Potential impact of global climate change on forest in Sri Lanka. In Erda L, Bolhofer W, Huq S, Lenhart S, Mukherjee S K, Smith J B, and Wisniewski J (eds.). Climate Change Variability and Adaptation in Asia and the Pacific. Dordrecht, The Netherlands: Kluwer Academic Publishers. 129-135 pp.

Sultana H and 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.

TERI (The Energy and Resources Institute). 2003. Coping with global change: vulnerability and adaptation in Indian agriculture. Monograph prepared on the occasion of COP-9. New Delhi: TERI. 26 pp.

TERI (The Energy and Resources Institute). 2005. Climate change and development: consultation on key researchable issues. India scoping study prepared for International Institute for Environment and Development, United Kingdom.

TERI (The Energy and Resources Institute). 2007. Addressing vulnerability to climate variability and change through an assessment of adaptation issues and options. Draft report submitted to the World Bank. New Delhi: TERI.

TERI (The Energy and Resources Institute) and IISD (International Institute for Sustainable Development). 2006. Designing policies in a world of uncertainty, change, and surprise: adaptive policy-making for agriculture and water resources in the face of climate change. Report to the International Development Research Centre. New Delhi and Winnipeg: TERI and IISD. 170 pp.

Tutu A U A and Kulsum U. 2005. Awareness to reduce vulnerability to climate change: Reducing Vulnerability to Climate Change (RVCC) Project. International Workshop on Community Level Adaptation to Climate Change. 16-18 January 2005, Dhaka, Bangladesh.

UNFCCC. 2007. Database on local coping strategies. http://maindb.unfccc.int/public/adaptation/

WHO (World Health Organisation). 2005. Human health impacts from climate variability and climate change in the Hindu Kush – Himalaya region. Report of an inter-regional workshop, Mukteshwar, India, October 2005.

World Bank. 2005. Natural disaster hotspots: a global risk analysis. Disaster Risk Management Series No. 5. Washington, DC: The World Bank Hazard Management Unit. 132 pp.

World Bank. 2006. Clean energy and development: towards an investment framework. Paper prepared for the Development Committee meeting on 23 April 2006 by the Environment and Socially Sustainable Development Vice Presidency and Infrastructure Vice Presidency. Washington, DC: The World Bank.