IPCC WGII Fourth Assessment Report – Draft for Expert Review

Chapter 10 - Asia

Coordinating Lead Authors
Hideo Harasawa (Japan), Murari Lal (India), Rex Victor Cruz (Philippines), Shaohong Wu (China)

Lead Authors
Yurji Anokhin (Russia), Punsalmaa Batima (Mongolia), Yashushi Honda (Japan), Mostafa Jafari (Iran), Congxian Li (China), Nguyen Huu Ninh (Vietnam)

Contributing Authors
Seita Emori (Japan), Daidu Fan (China), Hui Ju (China), Shuangcheng Li (China), Yoshiki Saito (Japan), Kiyoshi Takahashi (Japan), Tran Viet Lien (Vietnam), Qiaomin Zhang (China)

Review Editors
Daniel Murdiyaso (Indonesia), Shuzo Nishioka (Japan)

Contents

Executive Summary

There is increasing evidence since the publication of TAR that a distinct and significant warming trend has taken place in most parts of Asia over the last few decades. In general, annual mean precipitation at a number of observing stations in Asia has been decreasing continuously since 1970s; this decrease has become serious since 1990s. Increasing trends in the intensity and/or frequency of many of the extreme weather events such as heat waves, tropical cyclones, prolonged dry spells, intense rainfall, tornadoes, snow avalanches, thunderstorms, and dust storms on regional scales have been observed throughout the second half of the 20th century. Continuing emissions of greenhouse gases from human activities would result in significant changes in mean climate and its intraseasonal and interannual variability in Asia by the end of 21st century (*High Confidence*). An increase in sea surface temperature due to climate change would lead to sea level rise, more intense cyclonic storms, higher storm surges and an enhanced risk of disasters along the coastal regions of East, South and Southeast Asia (*High Confidence*).

Projected surface warming and shifts in rainfall in most countries of Asia are likely to be significant and will induce substantial decline in agricultural productivity (*High Confidence*) as a consequence of thermal stress and more severe droughts (lesser number of wet days) and floods (due to increased precipitation intensity) apart from soil degradation, coastal inundation and salt water intrusion due to sea level rise (in addition to increasing scarcity of arable lands). The net cereal production in South Asia is projected to decline at least between 4 to 10% by the end of this century under the most conservative climate change projections (*Medium Confidence*).

Climate change has the potential to exacerbate water resource stresses in most areas and ameliorate them in some parts of Asia. Freshwater availability in most countries of Asia is expected to be highly vulnerable to anticipated climate change. For example, about one billion people would be living in areas under severe water stress in South Asia in the next few decades. Increases in temperature and seasonal variability in precipitation are expected to result in rapid recession of Himalayan glaciers (*Medium Confidence*). Enhanced glacial melt would lead to increased summer flows in some river systems of Asia for a decade or two, followed by a reduction in flow as the glaciers recede. Major structural change and effective water-related policies, modification in lifestyle and technological transfer should lead to decreases in water withdrawals and hence water stress. More sustainable water use based on improvements in water use efficiency and marked changes in irrigation sector would be needed. Overexploitation of inshore and inland fisheries in most countries of East, South and Southeast Asia threatens fishery resources today. Changes in ocean currents, sea level, water temperature, salinity, wind speed and direction, strength of upwelling, and predators expected due to climate change will alter fish breeding habitat and food supply for fish and ultimately the abundance of fish populations in Asia. Coastal inundation has the potential to severely damage the aquaculture industry of Asia (*High Confidence*).

Many countries in Asia are vulnerable to heat stress. In East, South and Southeast Asia, endemic morbidity and mortality due to diarrhoeal disease primarily associated with effect of high temperatures on bacterial proliferation is most likely (*High Confidence)*. Increased coastal water temperature would significantly influence incidences of cholera. Outbreaks of vector borne diseases would follow droughts in humid regions. Climate change would also exacerbate threats to biodiversity resulting from land use/cover change and population pressure in most parts of Asia (*High Confidence)*. Ecosystem services would be impaired by loss of key species. Many species of mammals and birds and a large population of other species in Asia would be exterminated as a result of the synergistic effects of climate change and habitat fragmentation. The ecological security of wetlands including mangroves, and coral reefs around Asia would be under tremendous threat.

Exploitation of natural resources associated with rapid urbanization, industrialization, and economic development has led to increasing air and water pollution, land degradation, and other environmental problems in most countries of Asia, thus compounding the stress due to climate change. These multiple stresses have placed enormous pressure on urban infrastructure, human well being, cultural integrity, and socioeconomic arrangements in most megacities of Asia. Development of innovative solutions and adaptive strategies that deliver long term, sustainable livelihood for the developing countries of Asia are critical. Policies that reduce pressure on resources, improve management of environmental risks, and increase the welfare of the poorest members of society can simultaneously advance sustainable development and equity, and enhance adaptive capacity and coping mechanisms. Land use changes and the development of improved bioenergy systems that have been identified as important means of achieving sustainable rural development among small and poor land users in Asia have significant potential to contribute to climate change mitigation through sequestration and carbon substitution. The inclusion of sector specific climate proofing concept in the design and implementation of national development initiatives in most countries in Asia can help reduce their vulnerability to climate change.

10.1 Summary of knowledge assessed in the TAR

10.1.1 Climate change impacts in the Asia

The Third Assessment report (TAR) of the Intergovernmental Panel on Climate Change (IPCC), published in early 2001, re-iterated that while many systems and policies in Asia are not well adjusted even to today's climate and climate variability, continuing anthropogenic emissions of greenhouse gases are likely to result in significant changes in mean climate and its intraseasonal and interannual variability.

Extreme weather events in widely separated areas of Asia were reported to provide evidence of increases in the intensity or frequency on regional scales throughout the 20th century. The TAR reported that the area-averaged annual mean warming would be about 3°C in the decade of the 2050s and about 5°C in the decade of the 2080s over the land regions of Asia as a result of future increases in atmospheric concentration of greenhouse gases (IPCC, 2001). The rise in surface air temperature was projected to be most pronounced over boreal Asia in all seasons.

In general, an enhanced hydrological cycle and an increase in area-averaged annual mean rainfall over Asia were projected in the TAR. The TAR suggested that the increase in annual and winter mean precipitation would be highest in boreal Asia; as a consequence, the annual runoff of major Siberian Rivers would increase significantly. A decline in summer precipitation was likely over the central parts of arid and semi-arid Asia—leading to expansion of deserts and severe water stress conditions.

10.1.2 Vulnerability and adaptive strategies

The TAR reported that water and agriculture sectors are likely to be most sensitive to climate change-induced impacts in Asia. Agricultural productivity in Asia is likely to suffer severe losses because of high temperature, severe drought, flood conditions, and soil degradation. Forest ecosystems in boreal Asia would suffer from floods and increased volume of runoff associated with melting of permafrost regions. The dangerous processes of permafrost degradation resulting from global warming strengthen the vulnerability of all relevant climate-dependent sectors affecting the economy in high-latitude Asia. Countries in temperate and tropical Asia are likely to have increased exposure to extreme events, including forest die-back and increased fire risk, typhoons and tropical storms, floods and landslide, and severe vector-borne diseases. The stresses of climate change are likely to disrupt the ecology of mountain and highland systems in Asia. Glacial melt also is expected to increase under changed climate conditions. Sea level rise would cause large-scale inundation along the vast Asian coastline and recession of flat sandy beaches. The ecological security of mangroves and coral reefs around Asia would be put at risk.

The TAR highlighted that increase in income levels, education, and technical skills and improvements in public food distribution, disaster preparedness and management, and health care systems through sustainable and equitable development in developing countries of Asia should substantially enhance social capital and reduce the vulnerability of these countries to climate change. Specific adaptation strategies for countries in the Asian region were identified in the relevant sectors. Food security, disaster preparedness and management, soil conservation, and human health sectors were identified as crucial for countries with large populations. These countries must develop and implement incremental adaptation strategies and policies based on characteristics of system vulnerability such as resilience, critical thresholds, and coping ranges to exploit “no regret” measures and “win-win” options. Adaptations for human health essentially involved improving the health care system in many Asian countries. Adaptations to deal with sea-level rise, potentially more intense cyclones, and threats to ecosystems and biodiversity were recommended for high priority action in temperate and tropical Asian countries. It was suggested that the design of an optimal adaptation program in any Asian country must be based on comparison of damages avoided with costs of adaptation. Other factors also should enter the decision making process, such as the impacts of policies on society in terms of employment generation and opportunities, improved air and water quality, and the impacts of policies on broader concerns for equitable and sustainable development.

Subsequent to publication of the TAR, some advances in our ability to better understand the likely future state of social, economic, and environmental factors controlling the emission and concentration of greenhouse gases and aerosols that alter the radiative forcings of climate have been made. Further analysis of observed historical and current state of climatological state for several countries in the region has been reported which provide new knowledge on the current trends in climate and its variability including the extreme weather events. Details on future projections of climatic and environmental changes on finer scales also are now better understood. This chapter presents an update on the vulnerability and impacts of observed and projected climate change on various sectors and regions in Asia, examines how projected changes in climate could affect social, environmental, and economic sectors and identifies sector specific adaptation strategies for countries in the Asian region.

10.2 Current sensitivity and vulnerability

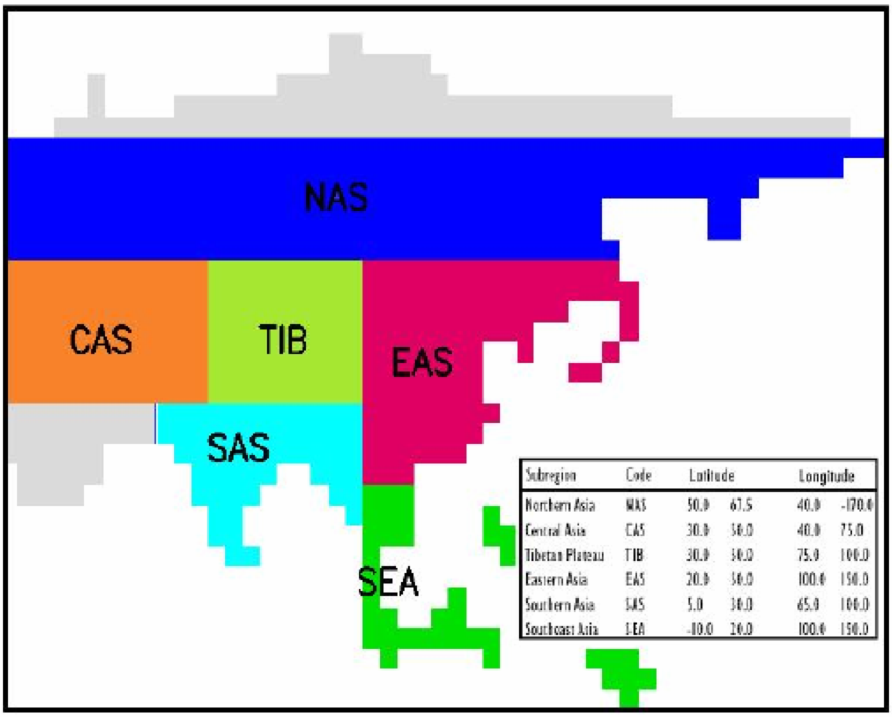
10.2.1 Asia: Regional characteristics

The Asian continent is bounded on the north by the Arctic Ocean, on the east by the Pacific Ocean, and on the south by the Indian Ocean; the western boundary, with Europe, runs roughly north-south along the eastern Ural Mountains, the Zhem River, the Caspian Sea, the Kuma-Manych Depression, the Black Sea, the Aegean Sea, the Mediterranean Sea, the Suez Canal, and the Red Sea.

The world's largest plateau - the Tibetan Plateau, with an average elevation of more than 4,000 m is located in Asia. Mt. Everest, the highest peak in the world (8,848 m), lies near the southern border of this plateau. The islands of Sri Lanka and Taiwan (China) and the archipelagos of Indonesia, the

Philippines, and Japan also are part of Asia. Asia is the most populous of the continents. Its total population in 2002 is reported to be about 3,902 million of which almost 61% is rural and almost 38.5% lives within 100 km of the coast. The coastline of Asia is 283,188 km long (Duedall and Maul, 2005).

For the purpose of generating the future climate scenarios and assessing the vulnerability and impacts to the projected future changes, the Asian continent has been divided into six subregions, namely, North Asia, Central Asia, Tibetan Plateau, East Asia, South Asia and Southeast Asia as illustrated in Fig. 10.1 below.



Subregion	Code	Latitude		Longitude	
Northern Asia	NAS	50.0	67.5	40.0	-170.0
Central Asia	CAS	30.0	50.0	40.0	75.0
Tibetan Plateau	TIB	30.0	50.0	75.0	100.0
Eastern Asia	EAS	20.0	50.0	100.0	150.0
Southern Asia	SAS	5.0	30.0	65.0	100.0
Southeast Asia	SEA	-10.0	20.0	100.0	150.0

***Fig. 10.1** Asia and its subregions as used in generation the climate change projections for SRES emission scenarios based on seven A-O GCM experiments*

*North Asia***,** located in Boreal climatic zone, has a mean monthly temperature of about -50°C in January and is the coldest region of the northern hemisphere in winter. Three Siberian rivers—the Ob, the Yenissey, and the Lena—contribute about 65.3% of total runoff from all rivers of the Arctic basin (ACIA, 2004). One of the world's largest and oldest (about 25-30 million years) lakes, Baikal, located in this region contains as much as 23000 km^3 of freshwaters covering nearly 20% of the world surface freshwater resources (Izrael and Anokhin, 2000). *Central Asia* includes 21 countries of predominantly arid and semi-arid region. Although the relief is mostly low, there are several peaks of 7,500 m or more in the Hindu Kush and Tien Shan mountain ranges; the lowest point in this region is the Dead Sea (-395 m). Many of the countries in this region are landlocked. *Tibetan Plateau* can be divided into three major parts, the east, north and south. The eastern part is forest region, occupying approximately one-fourth of the land. Natural forests run the entire breadth and length of this part of Tibet. The northern part is open grassland – it occupies approximately half of Tibet. The southern and central part is agricultural region, occupying about one-fourth of Tibet's land area. *East Asia* stretches in the east-west direction to about 5,000 km and in the north-south to about 3,000 km. Much of the natural forests in the region have long been destroyed. Broad plains have been cultivated and irrigated, and natural grasslands have been used for animal husbandry for centuries. *South Asia* is physiographically diverse and ecologically rich in natural and crop-related biodiversity. Although the present population of the region is principally rural, the region includes 5 of the 20 mega cities of which population is more than 10 million in the world (UN-HABITAT, 2004). Agriculture is the main industry in several countries of this region and is predominantly influenced by the monsoons. *Southeast Asia* is characterized typically by the tropical rainforest and monsoon climates.

Table 10.1 lists the total population, gross domestic product, total land area and land area classified under cropland, forest cover, annual internal water resources, and annual production of cereals, as well as per capita availability of fish and seafood in most of the countries of Asia (WRI, 2003; FAO, 2004a, b, c).

Table 10.1: *Key information on the socio-economics of some of Asian countries (WRI, 2003; FAO, 2004c)*

Country/Region	Mid-2004 population (thousands)	2004 GDP per captia (US$ 2001)	Land Area (10^3 ha)	Arable & Permanent Crops Land, 2002(103 ha)	Arable land (1000 ha)(FAO 1998-2002)	Total Forest Area, 2000 (103 ha)	Percentage of forest cover (FAO, 2000)	Natural RWR, 2002a (per capita m^3 per person)	Water resources: total renewable per capita (actual) (m3/inhab/yr)*	Average Production of Cereals, 1999-2001a (10^3 t)	Annual Sea Food, Avg. 1997-99a (per capita kg)
- Afghanistan	24926	x	65,209	8,054	7910	1,351	2.1	2,790	2835	3,257	x
- Armenia	3748	556	2,980	560	495	351	12.4	2,778	3427	301	0.5
- Azerbaijan	8447	688	8,660	2,009	1783	1,094	13.1	3,716	3649	1,528	0.9
- Bangladesh	137480	350	14,400	8,429	8019	1,334	10.2	8,444	8418	39,002	10.2
- Bhutan	2325	644	4,700	165	145	3,016	64.2	43,214	43379	159	x
- Cambodia	14482	278	18,104	3,807	3700	9,335	52.9	34,561	34476	4,197	12
- China	1313309	911	959,805	153,956	142621	163,480	17.5	2,186	2172	422,218	24.5
- Georgia	5074	594	6,970	1,064	799	2,988	43.7	12,149	12233	554	1.3
- India	1081229	462	328,726	170,115	161715	64,113	21.6	1,822	1807	234,313	4.7
- Indonesia	222611	695	190,457	33,700	20500	104,986	58	13,046	13070	58,954	19
- Iran	69788	1767	164,820	17,088	15020	7,299	4.5	1,900	2020	12,990	4.4
- Iraq	X	x	43,832	6,090	5750	799	1.8	3,111	3077	1,408	1.5
- Israel	X	x	2,214	424	338	132	6.4	265	265	197	23.4
- Japan	127778	32601	37,789	4,762	4418	24,081	64	3,372	3373	12,450	65.4
- Jordan	X	x	8,921	4,762	295	86	1	169	165	50	5.1
- Kazakhstan	15403	1503	272,490	21,671	21535	12,148	4.5	6,839	7086	14,049	1.9
- Korea, DPR	22776	x	12,054	2,700	2500	8,210	68.2	3,415	3422	3,550	9.4
- Korea, Republic	48199	8917	9,926	1,877	1684	6,248	63.3	1,471	1470	7,559	47.3
- Kuwait	X	x	1,782	15	13	5	0.3	10	8	3	12.1
- Kyrgyzstan	5208	308	19,990	1,411	1345	1,003	5.2	4,078	4062	1,657	0.7
- Laos	5787	326	23,680	1,001	920	12,561	54.4	60,318	60327	2,279	10
- Lebanon	X	x	1,040	313	170	36	3.5	1,220	1226	95	8
- Malaysia	25493	3699	32,975	7,585	1800	19,292	58.7	25,178	24202	2,212	57
- Mongolia	2630	433	156,650	1,200	1198	10,645	6.8	13,451	13599	156	0.1
- Myanmar	50101	162	67,658	10,611	9862	34,419	52.3	21,358	21403	21,322	16
- Nepal	X	x	14,718	3,294	3200	3,900	27.3	8,703	8542	6,874	1.1
- Oman	X	x	30,950	81	38	1	0	364	356	5	x
- Pakistan	157315	415	79,610	22,120	21448	2,361	3.1	2,812	1485	28,682	2.5
- Philippines	81408	912	30,000	10,700	5700	5,789	19.4	6,093	6096	16,917	29.6
Russia Federation	142397	2141	1,707,540	125,300	123465	851,392	50.4	31,354	31283	67,270	1.7
- Saudi Arabia	X	x	214,969	3,794	3600	1,504	0.7	111	102	2,293	7.6
- Singapore	4261	20733	68	2	1	2	3.3	x	143	x	x
- Sri Lanka	19218	849	6,561	1,916	916	1,940	30	2,592	2644	2,901	21.2
- Syrian Arab Republic	X	x	18,518	5,421	4593	461	2.5	1,541	1511	3,990	1.8
- Tajikistan	6298	169	14,310	1,057	930	400	2.8	2,587	2579	383	0.1
- Thailand	63763	1874	51,312	19,367	15867	14,762	28.9	6,371	6591	29,647	28.2
- Turkey	72320	2230	77,482	28,523	25938	10,225	13.3	3,344	3037	28,829	8
- Turkmenistan	4940	1097	48,810	1,915	1850	3,755	8	5,015	5156	1,358	1.7
United Arab Emirates	X	x	8,360	266	75	321	3.8	56	51	0	25.9
- Uzbekistan	26479	450	44,740	4,827	4484	1,969	4.8	1,968	1961	3,907	0.5
- Viet Nam	82481	411	33,169	8,895	6700	9,819	30.2	11,109	11102	33,909	18.1

10.2.2 Observed climate trends and variability

Past and present climate trends and variability in Asia is generally characterized by increasing surface air temperature which is more pronounced during winter than in summer. Increasing trend has been observed across the six subregions of Asia. The observed increases in some parts of Asia during recent decades are as much as 3°C per century. Increases in surface temperature are most pronounced in the North Asia.

High interseasonal, interannual and spatial variability in rainfall trend has been observed during the past few decades all across Asia. Decreasing trends in annual mean rainfall is observed in Russia, Northeast and North China, coastal belts and arid plains of Pakistan, along east coast of India, Indonesia and some areas in Japan. Annual mean rainfall exhibits increasing trends in western China, Changjiang valley and southeastern coast of China, Philippines, Arabian Peninsula and Bangladesh. *Table 10.2* lists some details on observed characteristics in surface air temperature and rainfall in Asian sub-regions.

Table 10.2: *Summary of key observed past and present climate trends and variability*

Region	Country	Change in Temperature	Change in Precipitation	References
North Asia	Russia	2 to 3°C rise in past 90 years, more pronounced in spring & winter	Highly variable, decrease during 1951-95, increasing in last decade	Savelieva, *et al*., 2000; Climate Change in Russia, 2003; Gruza & Rankova, 2004
	Mongolia	1.6°C rise in last 60 years, most pronounced in winter	5.5 mm/yr decrease in summer and 3.6 mm/yr on yearly basis	Gomboluudev, 2002; Batima *et al*., 2004a
Central Asia		1-2°C rise per century, no change during 1900-96	No clear trend during 1900-96 except 200% increase in Arabian Peninsula	???
	Northwest China	0.7°C increase from 1961-86 to 1987-2000	22%-33% increase	Shi *et al*., 2002
Tibetan Plateau		0.16 and 0.32°C per decade increase in annual and winter, respectively	Generally increasing in northeastern region	Liu and Chen, 2000; Yao *et al*., 2000 ; Cai *et al*., 2003; Liu *et al*., 1998 ; Zhao *et al*., 2004 ; Du and Ma, 2004
East Asia	China	Warming during last 50 years, more pronounced in winter than summer, rate of increase more pronounced in minimum than in maximum temperature	Annual rain decreased in past decade in Northeast, North China, increase in Western China, Yangtze Valley and southeastern coast	Hu *et al*., 2003; Zhai *et al*., 1999); Zhai and Pan, 2003
	Japan	~1.0°C in 20th century, 2 to 3°C rise in large cities		Japan Meteorological Agency, 2002; Ichikawa, 2004;
	Korea	0.23°C rise in annual mean per decade, increased diurnal range	More frequent heavy rain in recent years	Jung *et al*., 2002; Ho *et al*., 2003
South Asia	India	0.68°C increase per century, increasing decadal mean annual, warming pronounced during post monsoon and winter	Increase in extreme rains in northwest during summer monsoon in recent decades, lower no. of rainy days along east coasts	Lal, 2003; Lal *et al*., 2001; Lal *et al*., 1996 ; Kripalani *et al*., 1996; Singh and Sontakke, 2002
	Nepal	0.09°C per year in Himalayas and 0.04°C in Terai region, more in winter		Shresta, 2004
	Pakistan	0.6 to 1.0°C rise in mean temperature in coastal areas since early 1900s	10 to15% decrease in coastal belt and hyper arid plains	Farooq and Khan, 2004
	Bangladesh		Decadal rain anomalies above long term averages since 1960s	Mirza and Dixit, 1997 ; Mirza, 2002
	Sri Lanka		Increase trend in February and decrease trend in June	Chandrapala and Fernando, 1995; Chandrapala, 1996

SE Asia	General	0.1-0.3°C /decade between 1951-2000		Manton *et al.*, 2001
	Indonesia		Decreased in south, increased in north	Boer and Faqih, 2004
	Philippines	Increase in mean annual, maximum and minimum	Increase in annual rain beginning in 1980s and in number of rainy days in 1990s, increase in onset variability	Cruz *et al.*, 2005

10.2.3 Observed changes in extreme climatic events

New evidences on recent trends in the intensity and frequency of extreme weather events in Asia over the last century and into the 21st century are discussed below and summarized in **Table 10.3** below.

10.2.3.1 Heat waves

Significantly longer heat wave duration has been observed in many countries of Asia as indicated by pronounced warming trends and several cases of severe heat waves. Longer Heat Wave Duration (HWD) in the past decade has been reported for Siberia, Mongolia (Batima *et al*., 2005), most regions of China (Zhai *et al*., 1999; Zhai & Pan, 2003), India (De & Mukhopadhyay, 1998; Lal, 2003), Japan (Kawahara & Yamazaki, 1999), Korea (Choi *et al*., 2004; Ryoo *et al*., 2004) and most Southeast Asian countries (Manton *et al*., 2001; Tran Viet Lien, 2002; Tran Viet Lien *et al*, 2005; Cruz *et al*., 2005).

Table 10.3: *Summary of observed changes in extreme events and severe climate anomalies*

Country /Region	Key Features	Reference
Heat Waves		
Russia	Heat waves broke past 22-year record in May 2005	??
Mongolia	Number of heat wave duration has increased by 8-18 days in last 40 years, Temperatures higher than 49°C in 2000 caused fires in 0.66 M ha of forests and 4.2 M ha of pasture; Cold wave duration shortened by 13.3 days.	Batima *et al*., 2005
China	Increase in frequency of short heat wave in recent decade, increasing warmer days and nights in recent years	Zhai *et al*., 1999; Zhai and Pan, 2003
Japan	Increasing incidences of daily maximum temperature >35°C, decreasing extremely low temperature, in July 2004 more than 600 cases of heat stroke due to high temperature	Kawahara and Yamazaki, 1999
Korea	Increasing frequency of extreme maximum temperature with higher values in 1980s and 90s, decrease in frequency of low temperature 1958-2001	Choi *et al*., 2004; Ryoo *et al*., 2004
India	Frequency of hot days and multiple-day heat wave has increased in past century; Increase in deaths due to heat stress in recent years.	De and Mukhopahyay, 1998; Lal, 2003
Southeast Asia	Increase in hot days and warm nights and decrease in cold days and nights between 1961 and 1998	Manton *et al*., 2001; Tran Viet Lien, 2002; Tran Viet Lien *et al*., 2005; Cruz *et al*., 2005
Intense Rains and Floods		
Russia	Increase heavy rains in western Russia and decrease in Siberia, increase in number of days with more than 10mm rain, 50 to 70% increase in runoff of Siberia	Gruza *et al*., 1999; Gruza and Rankova, 2004; Izrael and Anokhin, 2001; Ruosteenoja *et al*., 2003
China	Increasing frequency of extreme rains in western and southern parts including Yangtze River, and decrease in northern regions, more floods in Yangtze in past decade, more frequent floods in Northeast China since 1990s, more intense summer rains in East China, severe flood in 1999, 7-fold increase in frequency of floods since 1950s	Zhai and Pan, 2003; Zhai, 2004, Zhai et a l., 1999; Ding and Pan, 2002
Japan	Increasing frequency of extreme rains in past 100 years attributed to frontal systems and typhoons, serious flood in 2004 due to heavy rains brought by 10 typhoons; during 1961-2000 increase in maximum rains observed from	Kajiwara *et al*., 2003; Isobe, 2002; Kawahara & Yamazaki (1999); Kanai *et al*., 2004

	120 stations	
South Asia	Serious and recurrent floods in Bangladesh, Nepal and Northeastern states of India during 2002, 2003 and 2004; A record 270 mm of rainfall in Mumbai, India on 31 July 2005 led to loss of over 1000 lives with loss of more than US$250 millions.	???
Southeast Asia	Increased occurrence of extreme rains causing flash floods in Vietnam, landslides and floods in 1990 and 2004 in the Philippines and floods in Cambodia in 2000	FAO, 2004a; Tran Viet Lien *et al*., 2005; Cruz *et al*., 2005; FAO/WFP, 2000; Environmental News Service, 2002
Droughts		
Russia	Decreased rain and increased temperature by 1°C cause droughts, 27 major droughts in 20th century 4 between 1972-81,	Golubev and Dronin, 2003; Meshcherskaya and Blazhevich, 1990
Mongolia	Increased droughts in recent years, droughts in 1999-2002 affected 70% of country	Natsagdorf *et al*., 2002; Natsagdorf, 2003; Batima, 2003
China	Increase in area affected by drought has exceeded 6.7 M ha since 2000 in Beijing, Hebei Province, Shangxi Province, Inner Mongolia and North China, increase dust storms affected area	Zhou, 2003; Chen *et al*., 2001
South Asia	50% of droughts associated with El Niño; Consecutive droughts in 1999 and 2000 in Pakistan and Northwest India led to decline in water tables, consecutive droughts in 2000 and 2002 caused crop failures, mass starvation and affected ~11 million people in Orissa	Webster *et al*., 1998
Southeast Asia	Droughts normally associated with ENSO years in Myanmar, Laos, Philippines, Indonesia and Vietnam, droughts in 1997/98 caused massive crop failures and water shortages, and forest fires in various parts of Philippines, Laos and Indonesia	Duong Lien Chau, 2000; PAGASA, 2001; Kelly *et al*., 2000; Glantz, 2001
Cyclones/ Typhoons		
Philippines	20 cyclones cross each year, number of severe cyclones increased from 2.8 per year in 1970-89 to 4.2 per year in 1990-2003	PAGASA, 2001
China	Number and intensity of strong cyclones increased since 1950s, 21 extreme storm surges between 1950 to 2004 of which 14 occurred during 1986-2004	Fan and Li, 2005
South Asia	Frequency of monsoon depressions and cyclones formation in Bay of Bengal and Arabian Sea on the decline since 1970 but intensity on increase causing worst floods in India in terms of damages to life and property	Lal, 2001; Lal, 2003
Cambodia, Vietnam	Tropical storm "Linda" seriously affected agriculture and fishery in Vietnam and Cambodia with damages in billions of dollars	
Japan	Frequency of typhoons increased in recent years - causing extensive damages to property	

10.2.3.2 Intense precipitation events and floods

Several recent studies have reported increasing frequency in occurrence of more intense rainfall events in many parts of Asia while the number of rainy days and total annual amount of precipitation has decreased in general. At some locations such as Tokyo, though, frequency of intense rainfall has exhibited a decreasing tendency due to decline in the hourly maximum rain in recent years (Kanai *et al*., 2004). More frequent heavy rains are noted in Siberia (Gruza *et al*., 1999; Izrael and Anokhin, 2001; Ruosteenoja *et al*., 2003; Gruza and Rankova, 2004), western and southern China including Yangtze River (Zhai *et al*., 1999; Zhai and Pan, 2003; Zhai, 2004), Japan (Kajiwara *et al*., 2003), Korea (Min *et al*., 2003), India, Nepal, Bangladesh and in countries of Southeast Asia (Manton *et al*., 2001; Lal, 2003; Tran Viet Lien *et al*., 2005; Cruz *et al*., 2005). Intense rainfall events in recent years have led to more severe flooding episodes, landslides, and debris and mud flows that affect vast low lying areas in Asia including the 31 million hectares of flood-prone areas in South and Southeast Asia (Mirza, 2002; FAO, 2004a).

10.2.3.3 Intensity and frequency of droughts

The rise in temperature particularly during the summer and normally drier months, and decrease in precipitation are commonly related to the increasing frequency and intensity of droughts in several parts of Asia including Russia (Meshcherskaya and Blazhevich, 1990). There are also evidences that most droughts are related to ENSO such as those observed in Pakistan, Bangladesh and India (Webster *et al*. 1998).The intensity of droughts appears to have also increased in terms of the areal extent and cost of damages as reported in a number of studies in Mongolia, China, India and several countries in Southeast Asia (Duong, 2000; PAGASA, 2001; Manton *et al*., 2001; Natsagdorf *et al*., 2003; Lal, 2002; Lal, 2003; Batima, 2003).

10.2.3.4 Intensity and frequency of cyclones/typhoons

Recent studies indicate that the frequency and intensity of tropical cyclones originating in the Pacific have increased over the last few decades (Fan and Li, 2005). In contrast, cyclones originating from the Bay of Bengal and Arabian Sea have been noted to decrease since 1970 but the intensity has increased (Lal, 2001). In both cases, the damages caused by intense cyclones have risen significantly with enhanced threats to the affected countries particularly India, China, Philippines, Japan, Vietnam and Cambodia (PAGASA, 2001).

10.2.4 Impacts of observed changes in climate trends and variability

10.2.4.1 Agriculture and food production

The cultivation potential has already been exhausted in many regions of Asia due to multiple constraints including land degradation and water scarcities. Both wheat and rice crops have been adversely affected by the observed changes in temperature regime and the changes in spatial and temporal variability of rainfall in several countries of Asia.

Frequent droughts particularly in Steppe zone, and longevity and severity of winter are inherent to many parts of Russia. About 80% of croplands in the erstwhile USSR are located in least productive thermal zone (Seljaninov, 1966). The 490 mm average annual precipitation along with severe droughts, short growing season and poor soils have limited agriculture potential of the erstwhile USSR (Anon., 2000). In recent years, production of cereals and feed grains was already below the desired level (Alcamo *et al*., 2004; Khomyakov & Kuznetsov, 2001). The increasing pressure of changes in climate and its variability would make it more difficult than it is already to step up the agricultural production to meet the growing demands in Russia. Increasing surface air temperature along with increasing intensity and frequency of El Niño, and reduction in number of rainy days have heightened the water stress in many agricultural areas in China lowering the production of wheat especially in the Yangtze Valley, the yield of pasture areas in Qianhai Province and the southern part of Gansu Province and corn production in Central China (Tao *et al*., 2003a; Jin *et al*., 2001; Tao *et al*., 2004). Rice and wheat production in the Indo-Gangetic plains of South Asia which increased in the 1970s and 1980s have in recent decade stagnated attributed to the rising (minimum) temperatures during the growing season and the resistance to weedicides that appeared in large areas under rice-wheat sequence (Agarwal *et al*., 2000). In Sri Lanka, 30 cm of soil has been eroded from upland tea plantations over the years while in the lowland tea plantation production has been adversely affected by soil erosion and increased soil moisture deficit brought about by increase in temperature and droughts (Wijeratne, 1996).

10.2.4.2 Hydrology and water resources

Changes in water withdrawals due to continuing population growth, economic activity and expansion of irrigation has led to an intensification of pressure on available water resources in most of the currently severely stressed river basins in Asia. Two key processes that have impacted the hydrology and water resources in Asia in the recent decades are (a) Thawing of permafrosts and degradation of frozen soils and (b) melting and retreat of glaciers.

Most permafrost occurs mainly in Siberia and the Far East of Russia, northern Mongolia, northeastern China, the Tibetan Plateau and the surrounding mountains. Approximately 55% of the Northern Hemisphere's land surface is covered by seasonally frozen ground, which can last for several months at high latitudes and high elevations (Zhang *et al*., 2003). Many cities and human settlements are located in the permafrost regions of North Asia where significant economic and development activities are limited by permafrost and to certain extent threatened by permafrost recession (Osterkamp *et al*., 2000; Jorgenson *et al*., 2001; Izrael *et al*., 2002; Fedorov and Konstantinov, 2003; Gavriliev and Efremov, 2003; Melnikov and Revson, 2003; Tumerbaatar, 2003; ACIA, 2004). As permafrost thaws, it jeopardizes both man-made structures and natural features (Izrael and Anokhin, 2001). Thawing permafrost on mountain slopes due to significant rise in air temperature in recent years (see *Table 10.4* below) has led to frequent landslides (Nelson, 2003).

Table 10.4: *Recent trends in permafrost temperatures measured at different locations (modified from Romanovsky et al., 2002)*

Country	Region	Permafrost temperature change/trends	Reference
Russia	East Siberia (1.6-3.2 m), 1960-1992	+0.03°C/year	Romanovsky *et al*., 2001
	North of West Siberia (10 m), 1980-1990	+0.3 to +0.7°C	Pavlov, 1994
	European North of Russia, continuous permafrost zone (6 m), 1973-1992	+1.6 to +2.8°C	Pavlov, 1994
	European North of Russia, discontinuous permafrost zone (6 m), 1970-1995	up to +1.2°C	Oberman and Mazhitova, 2001
Asia/China	Qinghai-Tibet Plateau (1970s-90s)	+0.1 to +0.3°C	Huijin *et al*., 2000
Asia/Kazakstan	Northern Tien Shan (1973-2003)	+0.2° to +0.6°C	Marchenko, 2002
Asia/Mongolia	Khentei and Khangai Mountains, Lake Hovsgol (1973-2003)	+0.3° to +0.6°C	Sharkhuu, 2003

The thickness of frozen soil in Tibet has decreased by 4 to 5 m while the water level in lakes has risen. The thinning of permafrost along the Qinghai-Tibetan Highway has accelerated by engineering activity in the area (Wang *et al*., 2004b). Significant permafrost degradation has been observed in China since 1970s as is evident from the increase in thawing depth from only 50 to 70 cm in the past to almost 100 cm in the 1990s while the soil temperature in the upper 20 cm layer has risen by 0.8^{o}C. The forest ecosystem such as spruce-fir forest which depends on the frozen soil has significantly degenerated since 1980s (Guo *et al*., 2001).

Melting of glaciers in Asia contribute substantially to the freshwater supplies in the region. In drier parts of Asia, wasting glaciers account for over 10% of fresh water supplies (Fitzharris, 1996; Meier, 1998). Glaciers in Asia are melting faster in recent years. Substantial melting of glaciers has been reported in Central Asia, Western Mongolia and Northwest China in recent decades. The glaciers on the Tibetan Plateau have also retreated rapidly since the 1980s (*see sub-section 10.6.2 below*). The magnitude of the glacial retreat is the largest at the south and east margins of the

Plateau (Pu *et al*., 2004). Foremost among the impacts of rapid melting of glaciers are the increase in glacial runoff and increased frequency of glacial lake outburst causing mudflows and avalanches such as observed in the Himalayan region (Bhadra, 2002).

Water shortages are critical in many countries of the predominantly arid region of Central Asia. Many countries in South and Southeast Asia have also reported severe water stress conditions in recent years. Decrease in available surface water and groundwater and the increase in water demand have contributed to water shortages in Vietnam, Philippines and Indonesia resulting to grave losses in crop production with adverse impacts on livelihood of millions of already poverty stricken families (Glantz, 2001). In parts of China, decrease in surface waters due to rise in temperature along with increasing water use have also caused water shortages leading to betrunking of rivers and drying up of lakes (Li *et al*., 2000). In India, Pakistan, Nepal and Bangladesh, water shortages have been attributed to rapid urbanization and industrialization, population growth along with inefficient water use and are aggravated by changing climate and its adverse impacts on demand, supply and water quality. In arid Central Asia, where water shortage is a perennial phenomenon; changes in climate and its variability will continue to challenge the ability of countries in the region to meet the growing demands for water (UNEP, 2002).

10.2.4.3 Oceans and coastal zones

Global warming and sea level rise in the coastal zone of Boreal Asia has influenced sea-ice formation and decay, thermo-abrasion process, permafrost and the time of river freeze up and breakup in recent decades (Leont'yev, 2004; ACIA, 2004). The monsoonal Asia coast is a high-risk cyclone-prone area with ~42% tropical cyclones of world's total (Ali, 1999). The most dangerous situation occurs when a severe cyclone with heavy precipitation lands on the river delta during the spring tide in a flood season. The superimposed extreme climatic and non climatic events together produce enormous coastal flooding, resulting in serious economic loss and numerous fatalities (Yang, 2000; Li *et al*., 2004a). Coastal erosion and wetland loss occur locally in the monsoon Asia coast. Wetlands in the major river deltas have significantly altered in recent years due to large scale sedimentation (Liu *et al*., 1998; Lu, 2003). Coastal erosion in Asia has led to loss of lands at rates dependent on varying regional tectonic activities and sea level rise (Du, 1997; Sin, 2000).

Saltwater intrusion in estuaries due to decreasing river runoff can be pushed 10-20 km further inland by the rising sea level (Huang and Xie, 2000; Shen *et al*., 2003; Yin *et al*., 2003; IUCN, 2003; Inam *et al*., 2003; Thanh *et al*., 2004). Saltwater from the Bay of Bengal is reported to have penetrated 100 km or more inland along tributary channels during the dry season (Allison *et al*., 2003). Severe droughts and unregulated groundwater withdrawal has also resulted in seawater intrusion in the coastal plains of China (Han *et al*., 1999；Ding *et al*., 2004).

Nearly 50% of world's Coral reefs are located in the shallow waters of Asia stretching from Red Sea and Indian Ocean to South China Sea and west Pacific Ocean (Spalding *et al*., 2001). Coral reefs (and mangroves) are ecologically important systems with highly concentrated biological activities of species that are especially valuable for maintaining biodiversity and/or resource productivity (Clark, 1996). Southeast Asia has both the largest area of coral reefs and the highest marine biodiversity in the world. It occupies an area of about 100,000 km^2 of coral reefs (nearly 34% of the world total) and contains over 600 of the almost 800 coral species. The Southeast Asia coastline also contains 51 of the world's 70 mangrove species, and 23 of the 50 sea grass species. The total annual benefit of sustainable coral reef fisheries across Southeast Asia is estimated to be US$2.4 billion (Burke *et al*., 2002). Over 34% of coral reefs of South, Southeast and East Asia were lost by the year 1998 (Wilkinson, 2000). About 16% of reef loss was attributed to anthropogenic factors, and 18% resulted from coral bleaching event associated with the 1997-98 El Niño event. Significant bleaching of Coral Reef in Okinawa islands, Japan and in maritime areas in Guangxi

Province and Hainan Province of China has also been reported in recent years in spite of conservation efforts (Wilkinson, 2002; Yamano and Tamura, 2004).

Several studies have pointed out positive correlations between fish abundance/diversity with structural habitat complexity or live coral cover (Jennings *et al*., 1996; Munday *et al*., 1997; Öhman and Rajasuriya, 1998; Öhman *et al*., 1998; Turner *et al*., 1999); alteration of habitats will affect the productivity of the ecosystem (McManus, 1996; Öhman *et al*., 1997). Consequently, the degradation of coral reef habitats in South and Southeast Asia also has secondary effects on the resource user groups, for example, subsistent fishermen and ornamental fish collectors, directly dependent on the reef products. Further, the reef related tourism in South and Southeast Asia is affected by the loss of recreational value of the coral reefs, due to low abundances of corals and certain fish species (Wilhelmsson *et al*., 1998; Westmacott *et al*., 2000).

The mangroves in Asia cover almost 41.5% of the world's total area and are abundant in Red River delta, Mekong delta, Ganges-Brahmaputra delta etc. The largest area of the world's arid-climate mangrove is located in Indus delta, with an area of 1600 km^2 and 4 species. However, these mangrove species have suffered serious degradation due to saltwater intrusion and reduction of freshwater in the Indus delta in recent years (IUCN, 2003). The over-exploitation of coastal areas due to various anthropogenic activities has also accelerated the degradation of mangrove forests. The destruction of mangroves also affects the fishery industries and coastal ecosystem balances (Zafar, 2005). In recent years, huge areas of Asian mangrove have been converted to shrimp ponds (Zafar, 2005). These shrimp farms, often with intense application of fertilizers, nutrients and antibiotics, have resulted in irreversible damage to mangroves. Destruction of mangrove ecosystems – primarily through deforestation – is quite extensive. More than half of the mangrove forests have been cleared in Indonesia during the past fifty years (Zafar, 2005). About 800,000 hectares of mangroves in Indonesia had been cleared by the 1980s for transmigration settlement.

Approximately one third of the mangroves in Malaysia were lost during the second half of the 20^{th} century (Zafar, 2005). Much of the mangrove forests in Singapore have been reclaimed for urban development (Zafar, 2005). Vietnam has lost many of its mangroves due to excessive pesticide use (Zafar, 2005). There are also reports on destruction of mangroves due to climatic factors such as reduction of freshwater flows and related processes like salt water intrusion in Indus delta (IUCN, 2003; Tablez *et al*., 2003).

10.2.4.4 Natural ecosystems

Forests, woodlands, grasslands, rangelands and deserts are vital to Asia's ecology. These natural ecosystems are rich sources of water, wood, land and other resources critical to the livelihood of many Asians and are home to many of the world's important plant and animal species (Jafari, 2003). However, establishment of human settlements, farming, grazing and many other human activities have caused extensive degradation of the natural ecosystems in the forests, woodlands and even rangelands.

There are reports of more intense and widespread forest fires in recent years in Asia (Shoigu, 2004). Wild fires in Russia contribute to more than half the amount of vegetation destroyed with the burnt areas in the forest exceeding 4.8 times those cut industrially. Annually, from 12000 to 38000 wild fires strike the protected Siberian forests affecting 0.5 to 3 million hectares (Vorobyov, 2004). As a consequence of 17% decline in spring precipitation and rise in surface temperature by 1.5^0C during the last 60 years, the frequency and areal extent of the forest and steppe fires in Mongolia have significantly increased over a period of 50 years. The economic loss caused by these forest fires has multiplied more than 100 times during the period of 1981-2001 (Erdnethuya, 2003). Forests in Southeast Asia are also under constant risk of fires induced by excessive dryness during prolonged dry season usually associated with ENSO. The 1997/98 ENSO event in Indonesia caused forest and brush fires in 9.7 million hectares, with serious domestic and trans-boundary pollution consequences. A total of 9,400 hectares of second growth and logged-over forests were also burned in the Philippines (Glantz, 2001).

With the gradual reduction in rainfall during the growing season for grass, aridity in Central Asia has increased in recent years, reducing growth of grasslands and increasing bareness of the ground surface. Increasing bareness has led to increased reflection of solar radiation, such that more soil moisture is evaporated and the ground has become increasingly drier in a feedback process, thus adding to the acceleration of grassland degradation (Zhang *et al.*, 2003). Many desert organisms in the region are already near their limits of temperature tolerance, and some may not be able to persist under hotter conditions.

10.2.4.5 Biodiversity

Biodiversity in Asia is being lost as a result of development activities and land degradation (especially overgrazing and deforestation), marine pollution, over fishing, hunting, and the overuse of freshwater (UNEP, 2002). Factors that are threatening biodiversity in central arid Asia include rapid changes in land use, extensive but poorly managed irrigation, more intensive use of rangelands, medicinal and food plant collection, construction of dams, and fuel wood collection. In South and Southeast Asia, agricultural expansion has caused serious damages to biodiversity. Loss of biodiversity have also resulted from the degradation of many natural flood plains in Asia due to habitat alteration, flow and flood control, species invasion and pollution (Gopal, 2004).

Information on biodiversity loss in Asia due to climate change remains limited to few countries. In East Asia, the plant and animal species are reported to be moving to higher latitude and altitude as a consequence of observed climate change in recent years in distribution of foliage, mammalian, insect, avifauna and fish. The flowering date of the Japanese cherry (*Prunus yedoensis*) is reported to be 5 days earlier now than 50 years ago (Ichikawa, 2004). A decrease in alpine flora has been reported in Hokkaido, the north island in Japan (Kudo *et al*., 2004) and other high mountains (Wada *et al*., 2004) while distribution of southern broad-leaved evergreen trees such as the Chinese Evergreen Oak in Japan has expanded. Nagasakiageha butterfly (*Papilio memnon thunbergii*), the northern border for which has been Kyushu and Shikoku Islands, appeared in Mie Prefecture in the 1990s, but have shifted to Tokyo area (Yoshio and Ishii, 1998; Oda and Ishii, 2001; Yoshio and Ishii, 2001). Wetlands in the Northeast China are being threatened by warmer climate in the recent decades. The precipitation decline in most areas of Sanjiang Plain during 1995 to 1999 resulted in drying up of wetlands and severe degradation of ecosystems. The recurrent droughts from 1999 to 2001 as well as the building of upriver reservoir and improper use of groundwater have led to drying up of the Momoge Wetland located in the Songnen Plain (Pan *et al*., 2003).

10.2.4.6 Human Health

Many countries in East, South and Southeast Asia are vulnerable to heat wave related mortality. The impacts of high temperatures in some south Asian countries are often exacerbated by recurrent power failures that affect cooling systems and hospital services. The heat wave related deaths in Indian state of Andhra Pradesh, Orissa and elsewhere in the past five years were reported to be mainly among the poor, elderly, and labourers such as rural daily wage earners, agricultural workers, labourers and rickshaw pullers, who have no option but to work outdoors in extreme weather (BBC News, 2002; Lal, 2002). Serious health risks associated with extreme summer temperatures and heat waves have been reported in Siberian cities too (Zolotov and Caliberny, 2004).

The number of flood disasters and their mortality impacts are heavily skewed toward Asia, where there are high population concentrations in floodplains of major rivers, such as the Ganges-Brahmaputra, Mekong and Yangtze basins, and in cyclone-prone coastal regions such as around the Bay of Bengal and the South China Sea. Heavy rainfall has been associated with an increase in outbreaks of enteric pathogens, usually as a result of a contamination of the water supplies. In tropical Asia, endemic morbidity and mortality due to diarrhoeal disease is associated with effect of high temperatures on bacterial proliferation (Checkley *et al*., 2000). Baseline prevalence of diarrhoeal disease is also linked to poverty and hygiene behaviour, rather than poor water quality. In India and Bangladesh, diarrhoeal diseases and outbreaks of other infectious diseases (e.g. cholera, hepatitis, vector-borne disease) have been reported to increase significantly after severe floods (Durkin *et al*., 1993). El Niño-related droughts are reported to have been associated with malaria outbreaks in Sri Lanka (Bouma and van der Kaay, 1996), suburb of Manila (Glantz, 2001) and Irian Jaya (Bangs and Subianto, 1999). Epidemics can follow drought in very humid regions, when river flow decreases sufficiently to allow mosquito breeding. In many desert fringe regions such as in Rajasthan bordering the Thar Desert, linakges between annual rainfall and malaria have been observed (Akhtar and McMichael, 1996).

The bimodal seasonal pattern of cholera in Bangladesh is reported to have followed sea surface temperatures in the Bay of Bengal and seasonal plankton abundance (a suggested environmental reservoir of the cholera pathogen, Vibrio cholera) (Colwell, 1996; Lobitz *et al*., 2000; Bouma and Pascual, 2001; Pascual *et al*., 2002). Interannual variability of cholera incidence in Dhaka, Bangladesh, between 1980 and 1998 was associated with ENSO (Pascual *et al*., 2000). An analysis of historical data for Bengal (1890-1940) indicates that El Niño related cholera outbreaks were confined to the coastal regions. The relationship between cholera and ENSO in Dhaka appears to have changed over time, becoming stronger in the last two decades (Rodo *et al*., 2002). Outbreaks of dengue or H-fever, diarrhea and cholera in various parts of the Philippines associated with ENSO of 1997/98 have also been reported. Poverty, lack of access to safe drinking water and poor sewerage system have exacerbated the spread of these communicable diseases in recent years (Glantz, 2001). Future rises in coastal water temperatures due to climate change may have direct influence on the abundance and/or toxicity of Vibrio cholera.

10.2.5 Other stressors

The dominant non-climatic stresses on water availability and quality are population increase, land use practices, land use changes, water-using technologies, costs of water treatment and remediation, and increasing demands on the hydrologic system to provide ecological and recreational services. Poverty, emerging and antibiotic-resistant infectious diseases, and environmental and occupational exposures that affect human health, particularly those that cause developmental problems or chronic disease, are also of continuing and growing concerns. Also of concern are expected rises in chronic diseases and diseases of elderly as the world's life expectancy increases.

Accurate understanding and description of the current and future impacts of climate change and variability on key ecosystems and resources hinge on a fair knowledge about how the impacts of climate change interact with changes in population, development, and land use and land cover changes. As described above, climate change can be quite potent in altering terrestrial ecosystems. The impacts of climate change can however be amplified or muted by population growth, development and land use and land cover change. Climate change is likely to increase country-scale inequity, within the present generation and between present and future generations, particularly in developing countries. Given this potential vulnerability, steps to lessen non-climatic stressors while strengthening adaptive and mitigative capacity could well enhance sustainable development.

10.2.5.1 Population growth

The Asia population has grown 2.57 times, from 1.44 billion to 3.69 billion, during 1950-2000. The growth of population is inextricably associated with the increasing pressure on the natural resources and the environment as the demands for goods and services expand. Utilization of natural resources almost inevitably entails alteration of the environment and ecosystems even when carried out in the most prudent manner. While changes in the environment and ecosystems can at times be beneficial the bottom line more often reflects net degradation than development. Some of the key impacts of increasing population include those linked with the intensification of use of natural forests including mangroves, agriculture, industrialization and urbanization.

In the developing world, the remaining natural flood plains are disappearing at an accelerating rate, primarily as a result of changes in hydrological cycle. The future increase of human population will lead to further degradation of riparian areas, intensification of the land and water use, increase in the discharge of pollutants, and further proliferation of species invasions. The most threatened flood plains will be those in South and Southeast Asia.

In Southeast Asia, population growth particularly in the uplands continues to exert pressure on the remaining forests in the region. Encroachment into forest zones for cultivation, grazing, fuel wood and other purposes has been a major cause of the loss and alteration of natural forests. Shifting cultivation being practiced by more than 20 million people inhabiting the uplands of the Philippines is the main source of forest degradation problem there (Pulhin, 2005).

In Asia, the pressure on land in the 21st century will increase due to the increasing food grain demand for the growing population, the booming economic development, as well as climate change. This will be exacerbated by the increasing scarcity of arable lands as a result of using vast agricultural lands to support industrialization and urbanization in pursuit of economic development (Zeqiang *et al*., 2001).

10.2.5.2 Development activities

Development to a large extent is responsible for much of the greenhouse gases emitted into the atmosphere that drives climate change. On the other hand development greatly contributes in reducing vulnerability to climate change and in enhancing the adaptive capacity of vulnerable sectors.

The rapid development of irrigation agriculture early in the 1960s led to a significantly large increase in water withdrawals from the Amu Darya and Syr Darya rivers in Central Asia. As a result, the Aral Sea has been shrinking at an alarming rate over the past four decades. The process taking place in the Aral Sea region could be referred to as anthropogenic desertification. The river deltas and other natural habitats in Aral Sea have been adversely affected. Serious health hazards have also occurred by extensive use of chemical fertilizers and pesticides that have contaminated both the soil and the water in the region.

Rates of both total forest loss and forest degradation are highest in Asia than anywhere else in the world. The conversion of forested area to agriculture in Asia during the past two decades occurred at a rate of 30,900 km^2 per year. In many developing countries of Asia, small scale fuel wood collection and industrial logging for exports of timber are also responsible for deforestation. For some countries in the Middle East, notably Kuwait, forest cover has increased greatly during the past decade – this is due to relatively little original tree cover in these arid countries, but also an increase due to policies of tree planting and availability of irrigation.

10.3 Future trends in climate and socioeconomic indicators

10.3.1 Future climate change scenarios

Climate change scenarios that are based on an ensemble of results as inferred from five A-O GCM experiments, namely those of CCSR-NIES (Japan), CSIRO (Australia), ECHAM4 (Germany), HADCM3 (UK) and NCAR-PCM (USA) for the six sub-regions of Asia on annual and seasonal mean basis are presented in **Table 10.5** below. The projections on likely increase in area – averaged surface air temperature and percent change in area – averaged precipitation (with respect to the baseline period 1961-1990) presented here are based on two extremes of the SRES scenarios corresponding to the highest (A1FI) and lowest (B1) emission pathways and for the four seasons and three 30 year time slices averaged over 2020s, 2050s and 2080s. Since not all of the said A-O GCM experiments have been conducted for all the six SRES scenarios, pattern scaling approach is followed for inferring these regional projections (Ruosteenoja *et al*., 2003: readers may refer to this reference to obtain future projections for other SRES emission pathways).

Table 10.5: *Projected changes in surface air temperature and precipitation for sub-regions of Asia under SRES A1FI (highest future emission trajectory) and B1 (lowest future emission trajectory) pathways for three time slices, namely 2020s, 2050s and 2080s.*

Sub-regions	Season	2010-2039				2040-2069				2070-2099			
		Temperature, deg C		Precipitation, %		Temperature, deg C		Precipitation, %		Temperature, deg C		Precipitation, %	
		A1FI	B1	A1FI	B1	A1FI	B1	A1FI	B1	A1FI	B1	A1FI	B1
North Asia	DJF	2.94	2.69	16	14	6.65	4.25	35	22	10.45	5.99	59	29
	MAM	1.69	2.02	10	10	4.96	3.54	25	19	8.32	4.69	43	25
	JJA	1.69	1.88	4	6	4.20	3.13	9	8	6.94	4.00	15	10
	SON	2.24	2.15	7	7	5.30	3.68	14	11	8.29	4.98	25	15
Central Asia	DJF	1.82	1.52	5	1	3.93	2.60	8	4	6.22	3.44	10	6
	MAM	1.53	1.52	3	-2	3.71	2.58	0	-2	6.24	3.42	-11	-10
	JJA	1.86	1.89	1	-5	4.42	3.12	-7	-4	7.50	4.10	-13	-7
	SON	1.72	1.54	4	0	3.96	2.74	3	0	6.44	3.72	1	0
Tibetan Plateau	DJF	2.05	1.60	14	10	4.44	2.97	21	14	7.62	4.09	31	18
	MAM	2.00	1.71	7	6	4.42	2.92	15	10	7.35	3.95	19	14
	JJA	1.74	1.72	4	4	3.74	2.92	6	8	7.20	3.94	9	7
	SON	1.58	1.49	6	6	3.93	2.74	7	5	6.77	3.73	12	7
East Asia	DJF	1.82	1.50	6	5	4.18	2.81	13	10	6.95	3.88	21	15
	MAM	1.61	1.50	2	2	3.81	2.67	9	7	6.41	3.69	15	10
	JJA	1.35	1.31	2	3	3.18	2.43	8	5	5.48	3.00	14	8
	SON	1.31	1.24	0	1	3.16	2.24	4	2	5.51	3.04	11	4
South Asia	DJF	1.17	1.11	-3	4	3.16	1.97	0	0	5.44	2.93	-16	-6
	MAM	1.18	1.07	7	8	2.97	1.81	26	24	5.22	2.71	31	20
	JJA	0.54	0.55	5	7	1.71	0.88	13	11	3.14	1.56	26	15
	SON	0.78	0.83	1	3	2.41	1.49	8	6	4.19	2.17	26	10
Southeast Asia	DJF	0.86	0.72	-1	1	2.25	1.32	2	4	3.92	2.02	6	4
	MAM	0.92	0.80	0	0	2.32	1.34	3	3	3.83	2.04	12	5
	JJA	0.83	0.74	-1	0	2.13	1.30	0	1	3.61	1.87	7	1
	SON	0.85	0.75	-2	0	2.22	1.32	-1	1	3.72	1.90	7	2

In general, projected warming over all sub-regions of Asia is higher during NH winter than during summer for all time periods. Most pronounced warming is projected at high latitudes in North Asia. Relatively higher increases in minimum temperature than in maximum temperature are projected over most of Asia on an annual mean basis, as well as during the winter—hence a decrease in DTR. Xu (2003) and Gao *et al*. (2003) suggested that the annual mean surface air temperature change over Tibet Plateau would be greater than the surrounding regions by the end of this century. The warming would be significant in high altitudes along Himalayas where the temperature increase can reach 3.4ºC. Recent modelling experiments with high resolution global climate models suggest substantial increase in annual mean temperature over Arctic regions, arid regions and highlands of Asia while the rise in temperature is lowest over western China and eastern Siberia (Uchiyama *et al*., 2005).

The inter-model differences are significantly large for the projections of precipitation change, suggesting rather low confidence in the future projections of regional precipitation. The precipitation will increase over most of the Plateau with the highest increase of about 40% in Southwestern and Northeastern part. An overall increase of only about 10 to 15% in summer monsoon precipitation is reported for the future over South Asia. The projected increase in area-averaged monsoon rainfall over the Indian subcontinent is within the currently observed range of interannual variability which is sufficiently large to cause devastating floods or serious drought. During winter, South Asia may experience between 5 and 25% decline in rainfall (Lal *et al*., 2001). The decline in wintertime rainfall is likely to be significant and may lead to droughts during the dry summer months. Hulme and Sheard (1999a, b) suggest that rainfall will increase across Northern Indonesia and the Philippines, and decrease over the southern Indonesian archipelago in the future. Downscaled GCM results suggest that total annual rainfall in Philippines would increase in future (Cruz *et al*., 2005). The average daily rainfall would decrease during the drier months (i.e., December to April) and increase during the wetter months (i.e., May to November).

10.3.2 Likely changes in extreme climatic events

Pronounced year to year variability in climate over East, South and Southeast Asia has been linked to ENSO. As global temperatures increase, the Pacific climate will tend to resemble a more El Niño-like state (Timmermann *et al*., 1999). An increased frequency of ENSO events and a shift in their seasonal cycle in a warmer atmosphere is suggested (Collins, 1999). The enhanced anomalous warming of the eastern equatorial Pacific Ocean has implications for increasing the likelihood of droughts and floods during summer in many of the East, South and Southeast Asian countries (Li and Xian, 2003). Future seasonal precipitation extremes in South and Southeast Asia associated with ENSO events are likely to be more intense (Ashrit *et al*., 2003).

An increase in tropical cyclone intensities is suggested in a warmer atmosphere (e.g., Walsh, 2004), though there is no conclusive evidence to suggest that cyclone frequencies or their preferred locations may change in the future. A possible increase in cyclone intensity of 10-20% for a rise in sea surface temperature of 2 to 4^{o}C relative to the current threshold temperature is very likely (Knutson and Tuleya, 2004). Amplification in storm surge heights should result from the occurrence of stronger winds with increase in sea surface temperatures and low pressures associated with tropical storms resulting in an enhanced risk of coastal disasters along the coastal regions of East, South and Southeast Asian Countries.

High resolution global climate models suggest a decline in the number of frost days over the Arctic, Tibet, eastern China, Korea and Japan (Uchiyama *et al*., 2005). An increase in extreme temperature range (ETR) is likely over Middle East countries, central India, western China through Central Asia and Indochina Peninsula while a decrease in ETR is suggested over Russia, the eastern half of China, Korea and Japan. Significant increases in growing season length are projected over eastern

Tibet, China's Yangtze River basin, Korea and Japan. A pronounced increase in heat wave duration index is likely over the arid regions and the highlands of Asia.

Several attempts have been made to generate more confident regional climate change scenarios using the data from an ensemble of regional climate modelling experiments covering East, South and Southeast Asia. These regional projections suggest that the annual mean area-averaged temperature over East Asia may increase by about 5ºC and precipitation would enhance by 6% (slightly warmer and wetter than the GCM based projections) by the end of this century (Kwon *et al*., 2004; Boo *et al*., 2005). Rise in temperature ranging from 2.2ºC over South China to 2.8ºC over North China is also projected. The precipitation would increase over central-west China by over 20% (Gao *et al*., 2001; 2002). Areas of precipitation decline are likely over Northeast and North China (up to –10%). The diurnal temperature range over most of Asia is likely to decrease due to the higher increase of minimum temperature. The number of hot spell days in summer will significantly increase while the number of cold spell days in winter will significantly decrease through out Asia.

A series of numerical experiments conducted with a high resolution regional climate model to assess future extreme climate events such as heat wave, heavy rainfall and typhoon over East Asia, including Japan and Korea (Emori *et al*., 2000; Kato *et al*., 2000; Sato, 2000; Ichikawa, 2004; Kurihara *et al*., 2005; Japan Meteorological Agency, 2005) suggest that heat wave conditions over Japan are likely to enhance in the future *(Fig. 10.2).* Extreme daily precipitation, including that associated with typhoon, would be further enhanced over Japan due to the enhancement of atmospheric moisture availability (Hasumi and Emori, 2004). The increases in summer mean precipitation over south Japan are also projected to be significantly large for the future *(Fig. 10.3).*

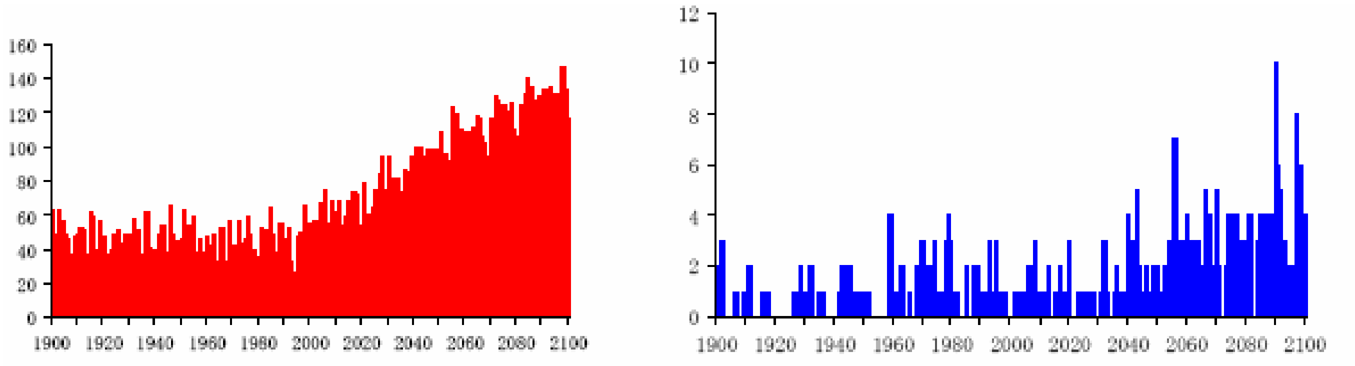


Fig. 10.2: *Predicted number of hot days (>30^{o}c) and heaby rainfall (>100 mm/day) by the high resolution GCM (Hasumi and Emori, 2004)*

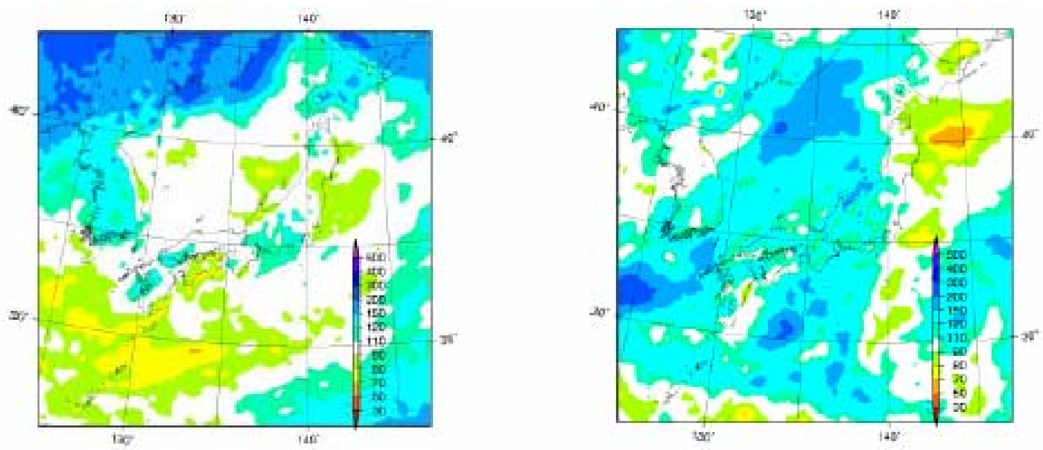


Fig. 10.3: *Predicted change in monthly mean rainfall during 2080 – 2100 period compared to 1981-2000 period predicted by high resolution regional climate model (left: Jan, right: July, Krihara, 2005).*

10.3.3 Sea level rise

During the 20th Century, the rate of global averaged sea level rise is estimated to be 1-2 mm a year, an order of magnitude larger than the average rate over the previous several millennia. The current rate of sea level rise in coastal areas of Asia is reported to be between 1 to 3 mm per year – marginally greater than the global average. A rate of sea-level rise of 3.1 mm per year has been reported over the past decade compared to 1.7-2.4 mm per year over the 20th century as a whole, which suggests that the rate of sea level rise has accelerated relative to the long term average.

For a quadrupling of greenhouse gas concentrations, global mean sea level rise from thermal expansion of oceans is projected to be between 1 to 4 meters (Church *et al.*, 2001). Warming over Greenland of 5.5ºC, which is consistent with mid-range greenhouse gas stabilization scenarios, would melt the Greenland ice sheet and could contribute to a sea level rise of about 3 meters in 1,000 years. A rapid collapse of the West Antarctic Ice Sheet leading to a sea level rise of several meters is very unlikely during the 21st Century. The rate and magnitude of sea-level change in the next century is likely to vary from region to region around the globe. However to date, there is little agreement as to the pattern of sea level rise.

10.3.4 Socioeconomic scenarios

The publication of the IPCC Special Report on Emissions Scenarios (SRES) in 2000 presented a useful starting point for impact assessors to construct a range of mutually consistent regional climate and non-climatic scenarios. In the SRES framework four narrative storylines (A1, A2, B1, B2) were developed which provide broadly qualitative and quantitative descriptions of regional changes on socio-economic development (e.g. population, economic activity), energy services and resource availability (e.g. energy intensities, energy demand, structure of energy use), land use and land cover, greenhouse gases and sulphur emissions, atmospheric composition (e.g. CO_2 concentration, tropospheric ozone and N-deposition). The Asia region includes all developing (non-Annex I) countries in Asia (excluding the Middle East). GHG emissions were quantified reflecting socio-economic development such as energy use, land use changes, industrial production process, and so on. The Population and GDP projections for Asia are illustrated in *Fig. 10.4*. The population growth shows a wide range among four scenarios; the differences between highest (SRES-A2) and lowest (SRES-A1 and B1) population scenarios are 1.54 billion people in 2050 and 4.5 billion people in 2100. For GDP growth, the highest economic growth is assumed in SRES-A1 scenario while the lowest economic growth is in SRES-A2 scenario. The GDPs in SRES-A1 scenario in 2050 and 2100 approach 4.2-fold and 3.6-fold of GDPs in SRES-A2 scenario respectively.

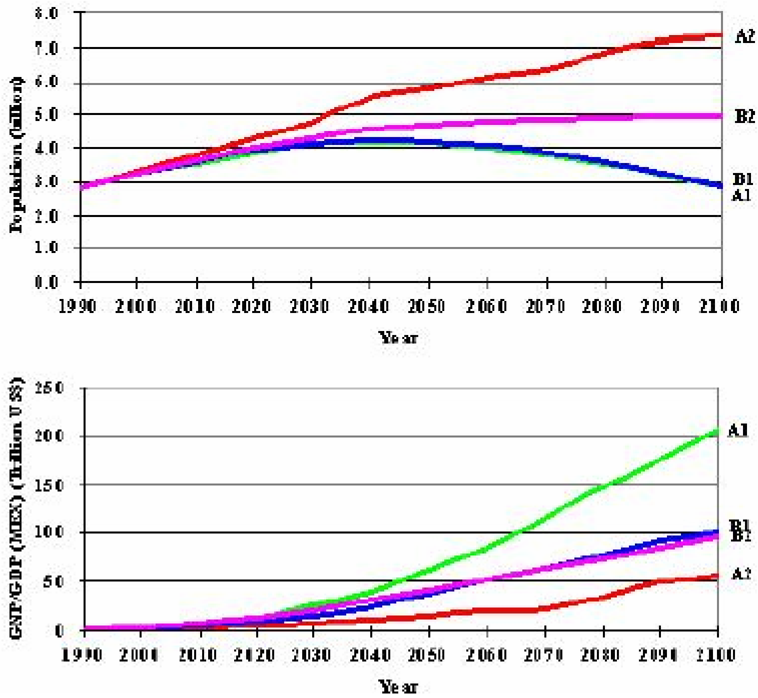


Fig. 10.4: *Population and GDP projections at ASIA region (IPCC-SRES Marker Scenarios)*

Following the SRES, several global scenarios (Post-SRES, GEO-3, etc) have been developed (Morita *et al*., 2001; UNEP, 2002). Furthermore, long-term GHG stabilization scenarios according to alternative development paths for major world regions, based on the non-intervention emission scenarios has been developed and GHG emissions from energy use, land use changes, and industrial production processes have been simulated over a wide range of mitigation policies adopted as responses to climate changes (Kainuma *et al*., 2003). The results demonstrate that: (a) to achieve stabilization at a different GHG concentration level, it is essential to have a policy package to reach the target concentration level, rather than a single policy; (b) energy efficiency improvement and introduction of renewable energy make a key contribution to the reduction of GHG emissions as a result of such a policy package; and (c) the developing world has the potential to substantially reduce GHG emissions with enhanced knowledge and technology transfer from the developed countries.

10.4 Key future impacts and vulnerabilities

10.4.1 Agriculture and food security

10.4.1.1 Production and quality

Substantial decreases in cereal production potential are expected as a consequence of climate change in Asia by the end of this century. As a consequence of the combined influence of fertilization effect and the accompanying thermal stress and water scarcity under the projected climate change scenarios, rice production in Asia could decline by 3.8% by the end of the 21st century (Murdiyarso, 2000). The projected warming accompanied by a 30% increase in tropospheric ozone and 20% decline in humidity is expected to decrease the grain and fodder productions by 26% and 9% respectively in North Asia (Izrael, 2002). In major crop export regions of Russia, the projected warming and a decline in summer precipitation threatens the potential production of important crops such as wheat, potatoes, maize and barley. Average potential grain production in Southern Russia is projected to drop by 7 to 29% in the 2020s and by about 23 to 41% in the 2070s (Alcamo *et al*., 2004). A 5 to 12% decline in net country wide grain production in Russia as a whole has been estimated by the 2070s. However, in the Far East and Southeastern Siberia, which is likely to get wetter under projected scenarios of climate change by 2070s, will be able to grow maize, pearl millet and sorghum.

Regional differences in the response of crop (wheat, maize, rice) yields to projected climate change are also significant (Parry *et al*., 1999, Rosenzweig *et al*., 2001). For example, studies suggest that, under the projected climate change scenarios, crop yields could increase up 20% in East and Southeast Asia while it could decrease up to 30% in Central and South Asia even through the direct positive physiological effects of CO_2 are taken into account. For the warming projections under A1FI emission scenarios (*see Table 10.5*), substantial decreases in crop yields have been suggested in parts of Asia with expected losses up to as high as 30% (Parry *et al*., 2004). The statistics on wheat productivity in past few decades suggests that its production potential is on the decline in large portions of South Asia and the southern part of East Asia (Fischer *et al*., 2002). The crop simulation modelling studies based on future climate change scenarios have indicated that substantial loses are likely in rainfed wheat in South and Southeast Asia (Fischer *et al*., 2002). For example, 0.5^{o}C rise in winter temperature would reduce wheat yield by 0.45 tonne per hectare in India (Lal *et al*., 1998; Kalra *et al*., 2003). Chinese rainfed wheat production has been projected to decrease by 4% to 7% by 2050 (Lin *et al*., 2004). Studies also suggest that a 2^{o}C increase in mean air temperature could decrease rainfed rice yield by 5-12% in China (Lin *et al*., 2004). In South Asia, the drop in yields in non-irrigated wheat and rice will be significant for a temperature increase of beyond 2.5^{o}C incurring a loss in farm level net revenue of between 9% and 25% (Lal *et al*., 1998). The net cereal production in South Asian countries is projected to decline at least between 4 to 10% by the end of this century under the most conservative climate change projections (Lal, 2005). The changes in cereal crop production potential indicate an increasing stress on resources induced by climate change in many developing countries of Asia.

10.4.1.2 Farming system and cropping areas

Climate change can affect not only crop production per unit area but also the area of production. Most of the arable land that is suitable for cultivation in Asia is already in use (IPCC, 2001). A decline in potentially good agricultural land in East Asia (including Japan) and substantial increases in suitable areas and production potentials in currently cultivated land in Central Asia are reported (Fischer *et al*., 2002). A northward shift of agricultural zones is likely such that the dry steppe zone in eastern part of Mongolia would push the forest-steppe to the north resulting in shrinking of the high mountainous and forest-steppe zones and expansion of the steppe and desert steppe (Baysgalan *et al*., 2000). Studies suggest that, by the middle of this century in northern China, tri-planting boundary will shift by 500 km from Yangtz River valley to Yellow River basin, and double planting regions will move towards the existing single planting areas, while single planting areas will shrink by 23% (Wang, 2002). Suitable land and production potentials for cereals may marginally increase in the Russian Federation and in East Asia (Fischer *et al*., 2002).

Agricultural crop distribution and production is largely dependent on the geographical distribution of thermal and moisture regimes. Changes in rainfall patterns, in addition to shifts in thermal regimes, influence local seasonal and annual water balances, and in turn affect the distribution of periods during which temperature and moisture conditions permit agricultural crop production. More than 28 million hectare area in South and East Asia requires strong expansion of irrigation for sustained productivity (FAO, 2003). For example, agricultural irrigation demand in arid and semi-arid regions of East Asia will increase by 10% for increase in temperature of 1^{o}C (Liu, 2002). The rainfed crops in the plains of north and northeast China would face water-related challenges in coming decades due to increases in water demands and soil-moisture deficit associated with projected decline in precipitation (Tao *et al*., 2003b).

Rising sea levels will severely affect the delta regions in South Asia where agriculture activity is most concentrated. In India, urbanization and industrialization will likely reduce the per capita availability of arable land from 0.15ha in 2000 to 0.08ha by 2020. While the estimated total requirement of food grains would be above 250 million tons by 2010, the gross arable area is expected to go up from 191 million hectare to only 215 million hectare by 2010 and this would require an increase of cropping intensity to around 150% (Sinha *et al.*, 1998). Since land is a fixed resource for agriculture, the need for more food in South Asia could only be met through higher yields per units of land, water, energy and time such as through precision farming. Enhanced variability in hydrological characteristics will continue to affect strategic grain supplies and food security of many nations in Asia. Intensification of agriculture will be the most likely means to meet the food requirements of the billions in Asia.

10.4.1.3 Livestock, fishery, aquaculture

Consumption of animal products such as meat and poultry has increased steadily in comparison to milk and milk products linked protein diets in the past few decades (FAO, 2003). However, in most regions of Asia (India, China, and Mongolia) pasture availability limits the expansion of livestock numbers. Cool temperate grassland is projected to shift northward with climate change and the net primary productivity will decline (Bolortsetseg and Gantsefseg, 2002; Sukumar *et al*., 2003, Christensen *et al*., 2004). The limited herbaceous production, heat stress from higher temperature, limited water intake due to decrease in rainfall could cause reduced milk yields in animals and increased incidence of some diseases.

In Asia and the Pacific, almost two-thirds of the major fish species currently remain either fully exploited or overexploited (FAO, 2004a). Future changes in ocean currents, sea level, sea water temperature, salinity, wind speed and direction, strength of upwelling, and predators to climate change have the potential to substantially alter fish breeding habitats and food supply for fish and ultimately the abundance of fish populations. The population in land locked countries and inland regions of Asia consume mostly freshwater fish. Fisheries at higher elevations are likely to be affected by lower oxygen availability due to rise in surface air temperatures. In the plains, the timing and amount of precipitation may also affect the migration of fish species from the river to the floodplains for spawning, dispersal, and growth (FAO, 2003). Overexploitation of inshore and inland fisheries in most countries of South and Southeast Asia threatens fishery resources as well as the livelihoods of the fishermen. Sea level rise may also cause saline water fronts to penetrate further inland, which could increase the habitat of brackish water fisheries and coastal inundation could significantly damage the aquaculture industry.

10.4.1.4 Future food supply and demand

Half the world's population is located in Asia. There are serious concerns about the prevalence of malnutrition among poorer and marginal groups, particularly rural children, and about the large number of people below the poverty line in many countries. Large uncertainties in our understanding as to how the regional climate change will impact the food supply and demand in Asia continue to prevail in spite of recent scientific advances. Because of increasing interdependency of global food system, the impact of climate change on future food supply and demand in Asia as a whole as well as in countries located in the region depends on what happens in other countries (Fischer *et al*., 2002). For example, India's surplus grain in past few years has been used to provide food aid to drought-affected Cambodia. However, increasing urbanization and population in Asia certainly will result in increased food demand and reduced supply due to limited availability of cropland area and yield declines projected in most cases (Murdiyarso, 2000; Wang, 2002; Lin *et al*., 2004).

Food supply or ability to purchase food directly depends on income and price of the products. The global cereal prices have been projected to increase more than three-fold by the 2080s as a consequence of decline in net productivity due to projected climate change (Parry *et al*., 2004). Localized increases in food prices could be frequently observed. Subsistence producers growing orphan crops, such as sorghum, millets, etc, could be at the greatest risk, both from a potential drop in productivity as well as from the danger of losing crop genetic diversity that has been preserved over generations. The risk of hunger, thus, remains very high in several developing countries of Asia since a large portion of population in majority of these countries are have low purchasing power.

Grasslands, livestocks, and water resources are likely to be most vulnerable to climate change in Central Asia because they are located mostly in marginal areas. Food insecurity and loss of livelihood is further exacerbated by the loss of cultivated land and nursery areas for fisheries by inundation and coastal erosion in low-lying areas of the tropical Asia. Management options, such as better stock management and more integrated agro-ecosystems could improve land conditions and counteract pressures arising from climate change.

10.4.1.5 Extreme climatic events and pests

Many recent studies (Rosenzweig *et al*., 2001; Natsagdorj *et al*., 2002; Kripalani *et al*., 2003; Zhang and Guo, 2004) have emphasized high confidence in the projected increase in the frequency and intensity of extreme weather events such as droughts, floods, tropical cyclones etc., particularly those associated with El Niño. Asia has most developing countries including some poorest countries in the world. All countries in Asia are particularly vulnerable to even the currently observed extreme weather events. Alterations in the patterns of extreme events, such as the increased frequency and intensity of droughts, will have much more serious consequences for chronic and transitory food insecurity than shifts in the patterns of average temperature and precipitation. These rainfall deficits can dramatically reduce crop yields and livestock numbers in rainfed production systems that are common in the semi-arid Asia. Humid areas in Asia are also vulnerable to changes in the length of the growing season and from extreme events, such as tropical cyclones.

Intensification of cropping provides greater host availability for pest. Damage by established pests can be severe and may change from year to year. Climate change as a driver will have different effects on the various types of pests. It may affect pest developmental rates and numbers of pest generations per year; or host plant susceptibility to pests. Huge losses in Asia due to unusual spread of pests (pathogens, insects and weeds) have been reported in the past few years (Oerke *et al*., 1995). Some studies (Rosenzweig *et al*., 2001; FAO, 2004c) concur that higher temperatures and longer growing season would result in increase in pest population in temperate regions of Asia. Warmer winter temperatures would reduce winter kill favouring the increase of insect population. Overall temperature increases may influence crop pathogen interactions by speeding up pathogen growth rates, which increases reproductive generations per crop cycle, by decreasing pathogen mortality due to cold winter temperatures, and by effects on the crop itself that leave the crop more vulnerable.

Climate change, as well as changing pest and disease patterns, will affect how food production systems operate in the future. This will have a direct influence on food security and poverty levels, particularly in countries with a high dependency on agriculture. In many cases, the impact will be felt directly by the rural poor, as they are often closely linked to direct food systems outcomes for their survival and are less able to substitute losses through food purchases. The urban poor can also be affected negatively because declining food production due to any of these factors will change food prices.

10.4.2 Hydrology and water resources

10.4.2.1 Water availability and demand

The most serious threat caused by climate change in Asia is water scarcity characterized by temperature increase and precipitation decrease. Climate change is likely to cause a major change in the variability of river runoff in some parts of Russia such that extremely low runoff events may occur much more frequently in the crop growing regions of the Southwest. Changes in seasonality and amount of water flows from river systems are likely to occur due to climate change. Some countries in Asia produce large amounts of hydropower; Tajikistan, for example, is the third-highest producer in the world (World Bank, 2002). Changes in runoff to the catchments of river basins could have a significant effect on the power output of these countries. The large river systems in the region, the Euphrates and Tigris, have a number of dams that are used for irrigation and water supply as well as for hydropower. If there is a reduction in total runoff due to climate change, the increased demand for agricultural and hydropower activities could place more pressure on water resources.

Under the projected precipitation scenarios, the glacier area over Tibetan Plateau is expected to shrink to 60%; from 1168 km^2 at present to 700 km^2 by the end of this century (Zhang and Liu, 1994). Warmer air temperatures will lead to changes in the distribution of seasonal snow cover and regime of snowmelt runoff. With the increases in discharge, the peak runoff period will also advance to May. At the same time, the percentage of ice melt water could drop from the current 25% to 18% by the end of this century. Water resources for irrigation from available surface and ground water sources in North China will meet only 70% of water requirement for agricultural production (Liu *et al*., 2001; Qin *et al*., 2002). In Northwest China, the faster glacier thawing will cause a rapid increase of water volume and rise of water level in glacier lakes, which could result in glacier lake crevasse and increase in frequency of mountain floods and debris flow (Wang *et al*., 2001). The widespread recession of glaciers in Asia will have many severe environmental impacts such as enhanced evaporation from grassland and wetland, shrinking and drying of lakes etc.

Glacial melt is projected to further increase leading to increased flows in some river systems for a few decades; this will be followed, however, by a reduction in flow as the glaciers disappear—creating larger areas of arid, interior deserts in low- and mid- parts of Central Asia. In parts of central Asia, regional increases in temperature will lead to an increased probability of events such as mudflows and avalanches that could adversely affect human settlements (Iafiazova, 1997). As mountain glaciers continue to disappear, the volume of summer runoff eventually will be reduced as a result of loss of ice resources. Consequences for downstream agriculture, which relies on this water for irrigation, will be unfavourable in most countries of South Asia. The thawing volume and speed of snow cover in spring is projected to accelerate in Northwest China and western part of Mongolia and the thawing time could advance, which will increase some water source, and may lead to flood in spring (Batima *et al*., 2004b). In Mongolia, significant shortages in wintertime water availability for livestock are projected by the end of this century (Erdenetsetseg, 2005).

Climate change will aggravate the instability of water resources and conflicts between supply and demand. Unless water resource conservation facilities are not strengthened in most countries of

Asia, the impacts of climate change on water resources system will enlarge. Water availability situation is bound to change with changing water withdrawals (due to socioeconomic and / or climate change) and / or changing water availability and would dominate the water stress (ratio of long term average of annual withdrawal to availability) conditions in many countries of Asia in the coming decades. Serious efforts are needed for more efficient groundwater recharge and harvesting of rainwater through identification, adoption and adaptation of technological options.

10.4.2.2 Water quality

The water quality of subsurface water is interlinked with quantity. Overexploitation of groundwater in many countries of Asia has resulted in a drop in its level leading to ingress of seawater in coastal areas making the subsurface water saline. India, China and Bangladesh are especially susceptible to increasing salinity of their groundwater as well as surface water resources especially along the coast due to increase in sea level as a direct impact of global warming (Han *et al*., 1999). Rising sea level by 0.4-1.0 m can induce saltwater intrusion 1-3 km more inland in the Zhujiang Estuary (Huang and Xie, 2000). Increasing frequency and intensity of droughts in the catchment area will lead to more serious and frequent saltwater intrusion in the estuary (Xu, 2003; Thanh *et al*., 2004; Huang *et al*., 2005) and thus deteriorate surface and ground water quality.

Lower levels of water due to excess withdrawing have also led to deterioration of water quality in many countries of South and Southeast Asia. Several problems of arsenic and fluoride contamination in water have surfaced in certain parts of India and Bangladesh. High levels of fluoride in water have led to acute cases of fluorosis in many villages of Andhra Pradesh, Rajasthan, Haryana, Tamil Nadu and Uttar Pradesh. Arsenic problem is rampant in West Bengal and has given rise to acute health problems in the State. More than 7000 wells in several districts in West Bengal have high dissolved arsenic usually more than 50 μg/litre today. Climate change will exacerbate the quality of ground water resources in countries of South and Southeast Asia.

10.4.2.3 Implications of droughts and floods

In some parts of Russia, extremely low runoff events are likely to occur more frequently due to climate change. The combination of severe pressure on water resources because of large water withdrawals, and more frequent occurrences of low runoff, may signal a significant threat to the water security of the population living in these regions. In many other areas of Russia, the frequency of extremely high runoff events may increase causing increased occurrence of floods. Projected increase in surface air temperature in northwest China will result in a 27% decline in glacier area (equivalent to the ice volume of 16184 km^3), in a 10 to 15% decline in frozen soil area, increase in flood and debris flow and more severe water shortage (Qin, 2002). The duration of seasonal snow cover in alpine areas namely Tibet Plateau, Xinjiang and Inner Mongolia will shorten and snow cover will thaw out in advance of spring season leading to a decline in volume and resulting in severe spring droughts. Between 20 and 40% reduction of runoff per capita in Ningxia, Xinjiang and Qinghai Province is likely by the end of 21st century (Tao *et al*., 2005). However, the pressure due to increasing population and social economic development on water resources is likely to be larger.

The per capita availability of freshwater including groundwater available in India is expected to drop from current availability of about 1905 m^3 to 1480 m^3 in the next decade due to increase in population coupled with no further augmentation of water resources and also its consequent decrease over the same time due to consumption. India will reach a state of water stress before 2025 when the availability falls below 1000 m^3 (CWC, 2001). The projected decrease in the winter precipitation over Indian subcontinent would reduce the total seasonal precipitation during

December, January and February implying a greater water stress during the lean monsoon period. Intense rain occurring over fewer days, which implies increased frequency of floods during the monsoon, will also result in loss of the rain water as direct runoff resulting in reduced groundwater recharging potential.

Expansion of areas under severe water stress will be one of the most pressing environmental problems in South and Southeast Asia in the foreseeable future as the number of people living under severe water stress is likely to increase substantially in absolute terms. For example, annual flow of Red river is projected to reduce by 13 to 19% and that of Mekong River by 16 to 24% by the end of 21st century (ADB, 1994). Major structural and technological changes (effective water-related policies, modification in lifestyle and technological transfer) should lead to decreases in water withdrawals and hence water stress. More sustainable water use based on improvements in water use efficiency and marked changes in irrigation sector (water use efficiency) would be needed.

10.4.3 Coastal and low lying areas

10.4.3.1 Sea level rise and coastal erosion

The global mean sea level is projected to rise between 9 and 88 cm by the end of 21st century (IPCC, 2001). Additional half a meter of sea level rise is projected for Arctic during this century (ACIA, 2004). The rising rates of sea level vary considerably from 1.5 to 4.4 mm per annum along the East Asia coast due to regional variation in land surface movement (Mimura and Yokoki, 2004). The projected rise of mean high water level can be one-time greater than that of mean sea level (Chen, 1991; Zhang and Du, 2000). The projected relative sea level rise (RSLR), including that due to thermal expansion, tectonic movement, ground subsidence and the trend of rising river water level, is 40-60cm, 50-70 cm and 70-90 cm in the Zhujiang, Changjiang and Huanghe Deltas, respectively by the year 2050 (Li *et al*., 2004a, b). Choi *et al*. (2002) has reported that the regional sea level rise over the Northwestern Pacific Ocean would be much more significant compared with the global average mainly due to exceptionally large warming near the entrance of the Kuroshio extension. The slope of the land and land surface movement would also affect the relative sea level rise in the Asian Arctic (ACIA, 2004).

In Asia, erosion is the main process that will occur to land as sea level continues to rise. As a consequence, structures built by humans will be destroyed by the sea while the shoreline retreats. In some coastal areas of Asia, a 30 cm rise in sea level can result in 4500 cm of landward erosion. Climate change and sea level rise tend to worsen the currently eroding coasts, turn the stable coasts into recession and slow accretion coasts (Huang and Xie, 2000). Sea level rise will accelerate coastal erosion by different coastal processes in various climate zones. In Boreal Asia coast, the relative sea level rise may reach up to 0.5 mm per annum by the end of this century. Coastal erosion will be enhanced as rising sea level and reducing sea ice allows higher wave and storm surge to hit the shore (ACIA, 2004). The coast recession can add up to 500–600 m in 100 years, with a rate of between 4 to 6 m per annum. The coastal recession by thermal abrasion is expected to accelerate 1.4 to 1.5 times in the second half of the 21st century as compared to the current rate (Leont'yev, 2004). In monsoonal Asia, reducing sediment flux is generally a main cause of coastal erosion. There is a clear reducing tendency of river sediment flux, and coastal erosion tends to more serious in Asia (Liu *et al*., 2001).

10.4.3.2 Inundation of coastal lowland

Coastal lowland tends to be inundated by rising sea level. Sea level rise also threatens the ecologically sensitive areas such as dunes, beaches and coastal wetlands, including salt marsh habitats and mangroves. Projected sea level rise could result in the number of people being flooded each year rising by many millions (Wassmann *et al*., 2004). The potential impacts of one meter sea level rise include inundation of an area of 5763 km^2 along the coastal States of India (TERI, 1996). Even under the most conservative scenario, sea level will be about 40 cm higher than today by the end of 21st century and this is estimated to increase the annual number of coastal population flooded from 13 million to 94 million. Almost 60% of this increase will occur in South Asia (along coasts from Pakistan, through India, Sri Lanka and Bangladesh to Burma), while about 20% will occur in Southeast Asia (from Thailand to Vietnam including Indonesia and the Philippines).

In coastal lowlands below the 1000-year storm surge elevations are widely distributed in Bangladesh, China, Japan, Vietnam, and Thailand, and hundred million people live in these areas (Nicholls, 2004). Flooding areas are related with the coastal protection level. It can be much less at highly protected coast like in economically developed Japan. In Japan, even under the present situation, an area of 861 km^2 of coastal lowland is located below high water level mainly in large cities like Tokyo, Osaka and Nagoya, where about 2 million people live and the assets cost US$ 540 billion. A one meter rise in sea level will increase the area at risk to 2,339 km^2, 2.7 times of the present; and population of 4.1 million at risk (Mimura and Yokoki, 2004). For one meter sea level rise with high tide and storm surge, the maximum inundation area is estimated to be 2,643 km^2 or about 1.2% of total area of the Korean Peninsula (Matsen and Jakobsen, 2004). A 30 cm rise in sea level will increase flooding areas by 5 or 6 times under non-coast-protection and existing-protection scenarios in the Changjiang and Zhujiang deltas, where the present coast protection level is high. The flooding areas in the Huanghe delta for a 100 cm rise in sea level are very close in non-protection and existing-protection scenarios, indicating that current protection level is insufficient to protect the coasts from high sea level rise (Du and Zhang, 2000; Li *et al*., 2004a). Improving flood management and protection will be required to reduce the risk of coastal flooding.

All coastal areas in Asia are facing an increasing range of stresses and shocks, the scale of which now poses a threat to the resilience of both human and environmental coastal systems, and are likely to be exacerbated by climate change. The projected future sea level rise could inundate low lying areas, drown coastal marshes and wetlands, erode beaches, exacerbate flooding and increase the salinity of rivers, bays and aquifers. With higher sea level, coastal regions would also be subject to increased wind and flood damage due to storm surges associated with more intense tropical storms. In addition, warming would also have far reaching implications for marine ecosystems in Asia.

10.4.3.3 Deltas, estuaries, wetland and other coastal ecosystems

Most types of world's major deltas are located in Asia. Future evolution of the major deltas in monsoonal Asia depends on changes in ocean processes and river sediment flux. Coastal erosion of the major deltas will be caused by sea level rise, intensifying extreme events (e.g. storm surge) due to climate change and excessive pumping of ground water for irrigation and reservoirs construction on the rivers. In the Tibetan Plateau and adjoining region, sediment starvation is generally the main cause of shrinking of deltas. Annual mean sediment discharge in Huanghe delta during the 1990s is only 34% of that observed during the 1950s and 1970s. The Changjiang sediment discharge will also be reduced by 50% after construction of the Three-Gorges Dam (Li *et al*., 2004b).

Urbanization in developing countries is proceeding exceptionally fast and mega cities with population more than 10 million are increasing in Asia. Many such mega cities in Asia are located on deltas formed during sea level change in the Holocene (Hara *et al*., 2004). These Asian mega cities with large population and intensified socioeconomic activities are subject to threats of climate change, sea level rise, storm surges, and coastal erosion. For a 1 m rise in sea level, half a million square hectares of Red river delta and from 1.5 to 2 million square hectares of Mekong river Delta is projected to be flooded. In addition, 250,000 hectares of mangrove will be completely lost, while approximately 100,000 hectares of cultivated farm land and sea product culturing area will become salt marshes (Tran Viet Lien *et al*., 2005). The changes in delta environment would have a significant impact on the human society (Mimura and Yokoki, 2004).

Saltwater ecosystems are characterized by high primary productivity and species diversity, providing habitats for migratory waterfowl, transient fish species and indigenous flora and fauna which are in turn served as nursery grounds for several fish and crustacean fisheries (Simas *et al*., 2001; Lu, 2003). Global warming and sea level rise will modulate environmental factors, such as water depth, water temperature, salinity in estuaries, which will influence flora growth rates, sexual reproduction patterns, and other physiological functions. Existing habitats will be redistributed, affecting estuarine flora distribution. The potential impacts of increasing CO_2 concentration and UV-B radiation will alter flora photosynthesis and productivity in estuaries (Short and Neckles, 1999). In most estuaries of Asia, the sedimentation rates are typically in excess of sea level rise, and the wetlands are renewable at substantial rates (Allison, 1998; Huang and Xie, 2000; Li *et al*., 2004a; Huang *et al*., 2005). China's initiative to restore wetlands along River Yangtse after it breached the embankments, and that of Malaysia to construct extensive wetlands in Putrajaya (near Kuala Lumpur) for storm water storage and treatment should help protect the wetlands in near terms. Plans need to be, however, developed for preventing degradation and restoration of wetlands in Asia on an extensive scale keeping in view the threats of future climate change so that the wetlands in Asia can be expected to regain a bit of their past glory in future, or at least to ensure that further degradation does not occur.

Among aquatic biota, microbes are greatly sensitive to environmental perturbations in estuaries. Estuarine habitats receive unprecedented pressure from population growth and economic development, eutrophicated by increasing human pollutant inputs (Paerl *et al*., 2003). Rise in temperature and eutrophication in the Zhujiang and Changjiang Estuaries have led to formation of the bottom oxygen-deficient horizon and increase in frequency and intensity of red tides (Hu *et al*., 2001). Projected increase in frequency and intensity of extreme weather events will exert adverse impacts on aquatic ecosystems.

Coral reefs are fragile coastal ecosystems sensitive to anthropogenic impacts and climate change. The heavy reliance on marine resources across Southeast Asia has resulted in the overexploitation and degradation of many coral reefs, specifically those near major population centres. The recent risk analysis of reefs suggests that almost 88% of the region's reefs are at risk from human activities; with half at 'high' to 'very high' risk (Burke *et al*., 2002). Between 24% and 30% of the reefs in South, Southeast and East Asia are projected to be lost during next 2-10 years and 10-30 years, respectively (14% and 18% for global), unless the stresses are removed and relatively large areas are protected (*Table 10.6*). In other words, the loss of reefs in South, Southeast and East Asia may be as high as 88% (59% for global) in the next 30 years (Wilkinson, 2004). If conservation measures receive increasing attention and investments, large areas of the world's reefs could recover from the direct and indirect damage by human activities within the next 10 years. However, if abnormally high sea surface temperatures continue to cause major bleaching events and reduce the capacity of reefs to calcify, most of these efforts will prove to be negative (Wilkinson, 2002).

***Table 10.6**: The 2004 status of coral reefs in selected regions of Asia (Wilkinson, 2004)*

Region/Years	Coral Reef Area (km^2)	Destroyed Reefs (%)	Reefs recovered (%) / reefs destroyed in 1998 (%)	Reefs at Critical Stage (%)	Reefs at Threatened Stage (%)	Reefs at Low or No Threat level (%)
2004						
Red Sea	17,640	4	2 / 4	2	10	84
The Gulfs	3,800	65	2 / 15	15	15	5
South Asia	19,210	45	13 /65	10	25	20
SE Asia	91,700	38	8 / 18	28	29	5
E & N Asia	5,400	14	3 / 10	23	12	51
Total Asia	137,750 (48.4%)	34.4	7.6/22.4	21.6	25.0	19.0

Note: Destroyed reefs: 90% of the corals lost and unlikely to recover soon; Reefs at a critical stage: 50% to 90% of corals lost or likely to be destroyed in 10 to 20 years; Reefs at threatened stage: 20 to 50% of corals lost or likely to be destroyed in 20 to 40 years.

A new study suggests that coral reefs, which have been severely affected by abnormally high sea surface temperatures in recent years, contain much more abundant unusual algal symbionts that are thermally tolerant and commonly associated with high temperature environments (Baker *et al*., 2004). This corals' adaptive response to climate change by shifting to new algal symbionts may protect devastated reefs from extinction or significantly prolong the extinction of surviving corals beyond previous assumption.

10.4.3.4 Marine fisheries and aquaculture

The Asia-Pacific region is the world's largest producer of fish, from both aquaculture and capture fishery sectors. In 2002, this amounted to 46.9 million tonnes from aquaculture (91% of global aquaculture production) and 44.7 million tonnes from capture fisheries (FAO, 2004a, b). Most of the growth in both aquaculture and capture fisheries has come from China and other South and Southeast Asian countries. Japan and Korea have shown a steady reduction in the supply of capture fish and consistent production in aquaculture in recent years. The fishery resources of Asia are being depleted by over fishing, excessive use of pesticide and industrial pollution. It is becoming increasingly evident that, to maintain the status quo in capture fisheries and aquaculture in the region, especially in terms of providing food security and poverty alleviation for the region's poor, a concerted and collaborative effort will be required.

The increase in marine culture products and decline in the marine fishery output is the current trends in commercial fishery activity. Recent studies suggest a reduction of primary production in the tropical oceans because of changes in oceanic circulation in a warmer atmosphere. The tunas catch of East Asia and Southeast Asia is nearly one-forth of the world's total. A modelling study showed significant large-scale changes of skipjack tuna habitat in the equatorial Pacific under projected warming scenario (Loukos *et al*., 2003). The impact of climate change on fishery depends on the complicated food chain in the ocean, which is likely to be disturbed by sea level rise, change in ocean currents, and alteration of the mixing layer thickness (IPCC, 2001). Arctic marine fishery would also be greatly influenced by climate change. Moderate warming is likely to improve the conditions for some economically gainful fisheries, such as cod and herring. Higher temperatures and reduced ice cover can increase productivity of their prey and provide more extensive habitats. In contrast, the northern shrimp will decrease with rise in sea surface temperatures (ACIA, 2004).

Marine fishes in China are facing threats from over fishing, pollution, red tide, and other climatic and environmental pressures. Main marine commercial fishes, like hairtail, little yellow croaker, and large yellow croaker, have obvious zoned distribution and seasonal feeding migration or spawning migration. The migration route and migration pattern, and hence regional catch, may greatly affected by global climate change (Su and Tang, 2002). Increased frequency of El Niño events likely in a warmer atmosphere could also lead to measurable declines in fish larvae abundance in coastal waters of South and Southeast Asia. These phenomena are expected to contribute to a general decline in fishery production in the coastal waters of East, South and Southeast Asia.

Aquaculture production is expected to continue its upward trend in the foreseeable future. However, climate change may have dramatic impacts on fish production, reducing the supply of fishmeal and fish oils. The market structure for fishmeal is a key factor in determining whether increasing aquaculture production can affect fishmeal prices (Asche and Tveteras, 2004). Increasing sea surface temperature has the potential to increase the intensity and frequency of disease outbreaks, exerting negative effects on marine aquaculture.

10.4.4 Natural ecosystems and biodiversity

10.4.4.1 Structure, production and function of forests

Climate change is virtually certain to drive the migration of tree species, resulting in changes in the geographic distribution of forest types and new combinations of species within forests. Generally, tree species are expected to shift southward or to higher altitudes. In addition, climate change will alter forest productivity depending upon location, tree species, water availability, and the effects of carbon dioxide fertilization. Increased temperatures could increase fire risk in areas that experience increased aridity, and climate change could promote the proliferation of diseases and pests that attack tree species. Such disturbances may be detrimental to forests themselves. Understanding how climate change will affect future forests, timber production and markets, however, is a complex task. Ecological and economic processes are exceptionally complicated, and understanding how integrated ecological and economic systems will respond to changing climate conditions remains a challenge.

Asia has many rare, endangered and threatened species per capita. Biodiversity is being lost here because of human activities, especially land degradation and the exploitation of resources. Moreover, up to 50% of the region’s total biodiversity is at risk due to climate change. The present distribution of species in high elevation ecosystems of Himalayas is projected to shift to higher elevations as a consequence of global warming, although the rates of vegetation change are expected to be slow and colonization success would be constrained by increased erosion and overland flows in the highly dissected and steep terrains. Many species and a large population of many other species will be exterminated as a result of the synergistic effects of climate change and habitat fragmentation.

As a consequence of climate change, no significant change in spatial patterns of productivity of the forest ecosystems in Northeast China is suggested (Liu *et al*., 1998). The areal coverage of broad-leaved Korean pine forests is projected to reduce by between 20% and 35% with a significant northward shift (Wu 2003). More than 90% of the dominant forest species Fagus crenata (beech tree) in Japan could disappear by the end of this century (Matsui *et al*., 2004a, b). Indonesia’s forests could benefit from carbon fertilization and will have a great capacity to absorb emissions if about 20 million hectare of estate crops and forest plantations are established by the year 2030. However, the occurrence of forest dieback and of time lag before the dominant plant types adjust to altered climate and/or migrate to new sites can not be ruled out. The overall impact of climate change on the forest ecosystems of Pakistan could be negative (Siddiqui *et al*., 1999).

The frequency of recurrence and intensity of thunderstorms in North Asia as a consequence of climate change would result in a 30 to 40% increase in occurrence of lightening and about 25% increase in the frequency of wild fires in forests (Vorobyov, 2004). Higher temperatures and drought conditions would lead to growth of many pests and diseases as well. If pest population grows, a chain reaction leading to serious consequences could occur. The potential crisis with high probability of forest fire will also increase local extension of many wild animals. Submergence of coastal areas due to sea level rise would lead to decreased habitat for breeding. With one meter rise in sea level the Sundarbans in Bangladesh will disappear and may spell the demise of the tiger and other wildlife there. The loss of habitat and wild species are at risk from changes in climate that favour forest fires and drought and from sea level rise.

Appropriate adaptation strategies are required to cope with climate change impacts on forest ecosystems in Asia. Reversing unsustainable trends in resource use and ecosystem health is an urgent priority. Biodiversity also faces newer challenges, such as those posed by the release into the environment of genetically modified organisms (GMOs). The *Cartagena Protocol on Biosafety* continues to raise issues about the relationship between the international environment and trade regimes. The need for conservation of biodiversity is now widely accepted, and there are various international treaties and agreements in place that aim to halt its rapid decline. However, for these agreements to be successful, they have to be enforced alongside other international agreements dealing with economic development, trade and investment, and the underlying causes of biodiversity loss must be identified and addressed.

10.4.4.2 Grasslands, rangelands and endangered species

Higher temperatures should, in general, improve the grassland productivity and prolong the pasturing time in alpine pasture, but the accompanying increase in evaporation will cause the decline of grassland productivity in areas with water scarcity. The natural grassland coverage and the grass yield in Asia, in general, are projected to decline with rise in temperature and higher evaporation (Lu and Lu, 2003). Large decreases in the natural capital of grasslands and savannahs are likely in South Asia as a consequence of climate change. Rise in surface air temperature and decline in precipitation is estimated to reduce pasture productivity in Mongolian steppe by about 10-30% except in high mountains and in Gobi where a marginal decrease in pasture productivity is projected by the end of this century (Batima, 2003). Traditional land use systems should provide conditions which would promote greater rangeland resilience due to the nomadic rangeland use, and would provide a better management strategy to cope with climate change in the region to offset the potential decrease of carbon storage and grassland productivity in the Mongolian Steppe under various climate scenarios (Ojima *et al*., 1998).

The location and areas of natural vegetation zone on the Tibetan Plateau will substantially change under the projected climate scenarios. The areas of temperate grassland and cold-temperate coniferous forest could expand while temperate desert and ice-edge desert may shrink. The vertical distribution of vegetation zone could move to higher altitude. Climate change may result in the shift of boundary of farming-pastoral transition region to the south in Northeast China, which can increase the grassland areas and provide favourable conditions for livestock production. However, as the transition area of farming-pastoral region is also the area of potential desertification, if protection measures are not taken in the new transition area, desertification may occur (Qiu *et al*., 2001; Li and Zhou, 2001). More frequent and prolonged droughts as a consequence of climate change and other anthropogenic factors together will result in the increasing trends of desertification in Asia.

10.4.4.3 Permafrosts

The permafrost thawing is expected to start over vast territories of North Asia under the projected climate change scenarios (Izrael *et al*., 2002). The perennially frozen rocks will completely degrade within the present southern regions of North Asia. In northern regions, mean annual temperature of frozen rocks and the depth of seasonal thawing will increase (**Fig. 10.5**). The change in the rock temperature will result in a change in the strength characteristics, bearing capacity, and compressibility of the frozen rocks, thaw settlement strains, frozen ground exploitability in the course of excavation and mining, generation of thermokarst, thermal erosion and some other geocryological processes (Climate Change, 2004). While the changes in physical properties can have some negative effects on infrastructure, the major threshold occurs when permafrost starts to thaw from its top down.

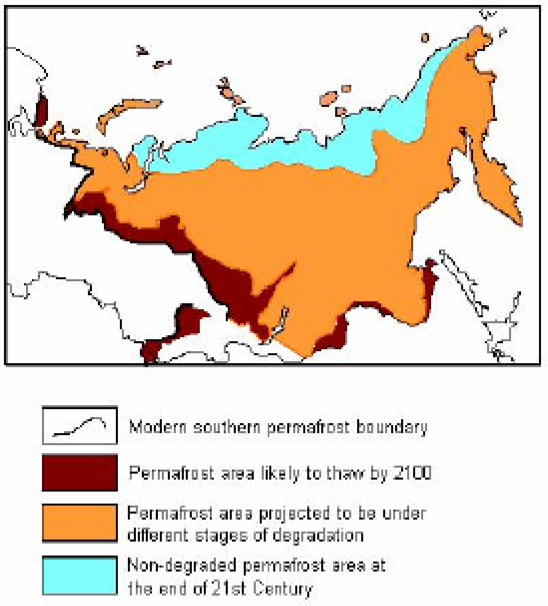


Fig. 10.5: *The projected permafrost boundary in North Asia as a consequence of degradation and thawing due to climate change.*

The most significant impacts on ecosystems, infrastructure, carbon cycle and hydrology will be observed in areas where permafrost contains a considerable amount of ground ice in the upper few meters. Permafrost degradation will lead to significant ground surface subsidence and pounding (Osterkamp *et al*., 2000; Jorgenson *et al*., 2001). Permafrost degradation on well-drained portions of slopes and highlands in Russia and Mongolia will improve the drainage conditions and lead to a decrease in the ground water content (Hinzman *et al*., 2003; Ganbaatar and Tumerbaatar, 2005). Changes in the active layer thickness and permafrost continuity will affect ground water and river runoffs. On Tibetan Plateau, in general, permafrost zone is expected to decrease in size, move upward and face degradation by the end of this century (Wu Qingbai *et al*., 2001). For a rise in surface temperature of 3^{o}C and no change in precipitation, most Tibetan Plateau glaciers of shorter than 4 km in length are projected to disappear and the glacier areas will reduce by more than 60% in the Changjiang Rivers source region by the end of this century (Shen *et al*., 2002).

Permafrost controls plant communities and biomass production by soil temperature, active layer thickness, moisture content, presence of unfrozen water, and surface hydrology. The changes in the permafrost thermal regime and active layer thickness can affect plant diversity and biomass. The thawing of the ice-rich permafrost within the boreal forest biome can lead to destruction of the substrate and major changes in ecosystems. Replacement of the boreal forest ecosystems with wetlands or by steppe-like habitats are likely (Izrael *et al*., 2002). Long-term permafrost degradation will continuously improve conditions for the subsurface water drainage (especially in sandy soils) that will lead to increased dryness of soils, putting significant stress on vegetation. Improved drainage conditions will also lead to shrinkage of numerous ponds within the degrading permafrost area and thus dramatically affect aquatic ecosystems (Yoshikawa and Hinzman, 2003).

10.4.5 Human health

Climate change poses substantial risks to human health in Asia. Altered patterns of temperature and precipitation due to climate change results in changes in the seasonality and geographic range of certain infectious diseases – including vector-borne infections such as malaria and dengue fever, and food-borne infections (*e.g*. salmonellosis) which peak during the summer months (WHO, 2003). The patterns of mortality in large urban populations have changed as a result of hotter summers and less cold winters. There is already evidence of widespread damage to human health by urban air quality and enhanced climate variability in Asia. Throughout Asia the emissions of sulfur dioxide have grown over the past few decades and as a result the urban air quality has deteoriated significantly contributing to widespread heat stress and smog induced cardiovascular and respiratory illnesses in the region (Huynen *et al*., 2001; WHO, 2004). As a consequence of climate variability and change, many Asian countries could face more instances of the diseases such as dengue fever, diarrheal disease, leptospirosis, cholera, acute respiratory infection (ARI), influenza, fish poisoning (ciguatera), pneumonia, and filariasis (WHO, 2004). Global warming will also enhance the number of incidences of some diseases, such as respiratory and cardiovascular diseases.

Negative influence of temperature anomalies on public health has been scientifically proven in Russia (Rachmanin, 2004). Exposure to higher temperatures appears to be a significant risk factor for cerebral infarction and cerebral ischemia during the summer months (Honda *et al*., 1998). Natural habitats of vector-borne diseases are reported to be expanding (Climate Change and Public Health in Russia in the 21st century, 2004). Prevalence of malaria and tick-borne encephalitis has also increased over time in Russia (Yasukevich and Semenov, 2004; Matuschenko *et al*., 2004). The distribution of vector-borne infectious diseases such as malaria is influenced by the spread of vectors and the climate dependence of the infectious pathogens. There are reports on the possible effects of pesticide resistance of a certain type of mosquito on the transition of malaria type (Singh *et al*., 2004). The insect-borne infectious diseases strongly modulated by future climate change include malaria, schistosomiasis, dengue fever and other virus disease (Kovats *et al*., 2003). Oncomelania is strongly influenced by climate and the infection rate of schistosomiasis is the highest in temperature range of 24^oC to 27^oC. Temperature can directly influence the breeding of malaria protozoa and suitable climate conditions can intensify the invasiveness of mosquito (Tong and Ying, 2000). A warmer and more humid climate would be favourable for propagation and invasiveness of infectious insect vector.

Warmer sea surface temperatures along coastlines of South and Southeast Asia would support higher phytoplankton blooms. These phytoplankton blooms are excellent habitats for survival and spread of infectious bacterial diseases such as cholera (Pascual *et al*., 2002). Water-borne diseases including cholera and the suite of diarrhoeal diseases caused by organisms such as giardia, salmonella and cryptosporidium could also become common with the contamination of drinking water quality. Precipitation increase and frequent floods, and sea level rise in future will deteriorate the surface water quality owing to more pollution, and hence lead to more water-borne infectious diseases such as dermatosis, cardiovascular disease and gastrointestinal disease. For preventive actions, impact assessments are necessary on the various aspects such as nutritional situation, drinking water supply, water salinity and ecosystem damage. The risk factor of diseases will depend on improved environmental sanitation, the hygienic practice and medical treatment facilities.

Bird flu (HPAI virus infection) have struck a massive attack on the livelihoods of rural population in many East and Southeast Asian countries, especially in China, Thailand, Viet Nam and Indonesia during the recent years where poultry raising is one of the major income sources (FAO, 2005). Demographic factors, increase in trade and traffic, agricultural intensification, land use practices and climate change contribute to increased epidemiological instability. The explosive poultry and pig production increases may have played a role in the evolution, emergence and spread of the pathogen. Migratory birds have been identified not only as culprits in the spread of HPAI but also as the primary amplifying host in a bird-mosquito-bird cycle spreading West Nile Virus (WNV) to elsewhere, including across South and East Asia (FAO, 2005). Severe Acute Respiratory Syndrome (SARS) was caused by a previously unrecognized animal corona virus that found its way to the "wet markets" in southern China and adapted to become a virus readily transmissible to humans.

Health outcomes in response to climate change are currently the subject of intense debate. Climate is one of a number of factors influencing the incidence of infectious diseases. Studying the impact of climate variability and climate change on human health requires appropriate specification of the meteorological "exposure". Climate change is one of several concurrent environmental changes (*e.g.*, urban air quality) that simultaneously affect human health – often interactively. The pattern of transmission of vector-borne infectious diseases in relation to climatic conditions, population movement, forest clearance and land-use patterns, biodiversity losses (*e.g.*, natural predators of mosquitoes), freshwater surface configurations, and human population density needs to be examined. A better understanding of the interaction among climate change, environmental and health status in communities at regional and local scales is crucial to forge physiological acclimatization and social adaptation.

10.4.6 Human dimensions

10.4.6.1 Climate extremes and migration

In Asia migration remains dominant, providing for 64% of urban growth (Pelling, 2003). Total population, international migration and refugees in Asia and the Pacific region currently are estimated to be 3,307 million, 23 million, and 4.8 million respectively (UN-HABITAT, 2004). Future climate change is expected to have considerable impacts on natural resource systems, and it is well-established that changes in the natural environment can affect human sustenance and livelihoods. This in turn can lead to instability and conflict, often followed by displacements of people and changes in occupancy and migration patterns. Therefore, as hazards and disruptions associated with climate change grow in this century, so, too, may the likelihood of related population displacements.

Climate-related disruptions of human populations and consequent migrations can be expected over coming decades. Such climate-induced movements can have effects in source areas, along migration routes and in the receiving areas, often well beyond national borders. Periods when precipitation shortfalls coincide with adverse economic conditions for farmers (such as low crop prices) would be those most likely to lead to sudden spikes in rural-to-urban migration levels that might lead to socio-political unrest in China and India. Climatic changes in Pakistan and Bangladesh would likely exacerbate present environmental conditions that give rise to land degradation, shortfalls in food production, rural poverty and urban unrest. Circular migration patterns such as those punctuated by shocks of migrants following extreme weather events could be expected. Such changes would likely affect not only internal migration patterns, but also migration movements to other western countries.

Food can be produced on currently cultivated land if sustainable management and adequate inputs are applied. Attaining this situation would also require substantial improvements of socioeconomic conditions of farmers in most Asian countries to enable access to inputs and technology. Land degradation, if continued unchecked, may further exacerbate land scarcities in some countries of Asia. The aggregate impacts of climate change become more favourable with multiple cropping and with consideration of irrigation. Concerns for the environment as well as socioeconomic considerations may infringe upon the current agricultural resource base and prevent land and water resources from being developed for agriculture. The production losses due to climate change may drastically increase the number of undernourished in several developing countries in Asia, severely hindering progress against poverty and food insecurity.

10.4.6.2 Urban development and infrastructure linkages

Many of these infrastructure systems are vulnerable to a variety of anthropogenic or natural disruptions even though their functioning is vital to the creation and maintenance of quality of life in a region. Dealing appropriately with immediate infrastructure vulnerabilities and infrastructure evolution requires a combination of effective short-term crisis management and anticipatory, strategic thinking and planning. Both the "material nature" and institutional issues surrounding urban infrastructure in a changing environment pose formidable challenges to efforts by industrial ecologists to improve the sustainability of urban areas.

The compounding influence of future rises in temperature due to global warming, along with increases in temperature due to local urban heat island effects, makes cities more vulnerable to higher temperatures than would be expected due to global warming alone. Existing stresses in urban areas include crime, traffic congestion, compromised air and water quality, and disruptions of personal and business life due to decaying infrastructure. Climate change is likely to amplify some of these stresses, although all the interactions are not well understood. For example, it has been suggested that climate change will exacerbate the existing heat island phenomenon in cities of Japan by absorbing increased solar radiation (Shimoda, 2003). This will lead to further increases in temperatures in an urban microclimate with negative implications for energy and water consumption, human health and discomfort, and local ecosystems. Vulnerabilities and dynamics of urban infrastructures in megacities of Asia to long term impacts of projected climate change need to be worked out in terms of energy, communication, transportation, water run-off, and water quality, as well as the interrelatedness of these systems, and implications for public health (WHO, 2003).

10.4.6.3 Industry, energy, and transportation

The direct impact of global warming on industry and energy at the level currently projected from climate fluctuations and changes (significance, speed, time period) is expected to be quite small because such impact will be handled by unutilised capacity to meet changing demands and long-term facility renewal to deal with changing supply. However, in a country such as Japan that depends on overseas sources for about 80% of its energy and 60% of its food, it is impossible to predict the size and complexity of secondary and tertiary impacts of global warming. In a study on assessment of impacts of future climate change on ski industry following a relationship between daily snow depth and number of skiers in seven ski areas of Japan, Fukushima *et al*. (2002) reported more than 30% drop in visiting skiers in almost all ski areas in Japan except northern region (Hokkaido) and / or high altitude regions (centre of the Main Island) in the event of a 3^{o}C increase in air temperature. Table 10.7 provides some examples of the direct effects of changes due to global warming on the industrial and energy (electric power) sectors.

Table10.7: *Sensitivity of industries to climate change (Harasawa and Nishioka, 2003)*

Element	Industry	Energy (Electricity)
Change in amount and pattern of rainfall	Water Demand (Industry, Municipal water use) Water Deficit/drought and Food/product manufacturing	Hydraulic power generation. management and control of dam facilities, Reservation of cooling water
Temperature Increase	Cooling/Warming apparatus Insulated house/building Industries sensitive to seasonal change Winter: clothing, air conditioner Summer: summer product, vebaledy	Control of snow melt water to dam and storage
Water Temperature Increase (Sea water, fresh water)	Demand for natural gas to heating water of aquaculture	Decline of turbine efficiency (electric generation), increase in adhesion living thing
Sea Level Rise	Location of reinsure industry, embankment	Inundation to coastal facilities/equipments
Moisture		Demand for air conditioner/cooler
Typhoon	Factory/facility, transportation/communication, Information apparatus industry	Typhoon proof design, measures to salt water, thunderstorm, snowfall, natural energy generation(wind energy)

If the mean June–August temperature rises by 1°C in Japan, consumption of summer products such as air conditioners, beer, soft drinks, clothing, electricity are projected to increase about 5% (Harasawa and Nishioka, 2003). *Table 10.8* lists a summary of impacts on global warming on industries and energy sectors identified in Japan.

Table 10.8: *Impacts of climate change on industries and energy sectors*

Changes in Climate parameters	Impacts
1^{o}C temperature increase in June to August	About 5% increase of consumption of summer products
Extension of high temperature period	Increase of consumption of air conditioners, beer, soft drinks, ice creams
Increase in sunder storms	Damage on information devices and facilities
1^{o}C temperature increase in Summer	Increase in electricity demand by about 5 million kW Increase in electricity demand in factories to enhance production
Increase in annual average temperature	Increase of household electricity consumption in southern Japan Decrease in total energy consumption for cooling, warming in northern Japan
Change in amount and pattern of rainfall	Hydro electric power generation, management and implementation of dams, cooling water management
1^{o}C increase in cooling water	0.2 – 0.4% reduction of generation of electricity in thermal power plants, 1 2% reduction in nuclear power plant

South Asia is expected to account for one-fifth the world's total energy consumption by the end of 21st century (Parikh and Bhattacharya, 2004). Among various components, coal would continue to contribute till the middle of the 21st century while biomass will lose its share steadily. Gas, electricity, district heating and methanol would grow in shares only during the later half of the 21st century. A complete reversal in sectoral shares is expected during this period when, the industrial sector is to take over while the non-commercial sector is likely to be eliminated. The residential and transport sectors' energy consumption is also expected to increase significantly. South Asia is projected to emerge as the largest energy sector investment market in the world by 2100. The investment requirements for this sector are likely to increase by more than fifteen-fold in the least, by the end of 21st century. However, the investments to GDP ratio show a decline over the years, indicating energy intensity improvements and continuous progress along technological learning curves. Among various sectors, the electricity sector calls for the highest investments, estimated between 40% and 60% of total energy sector investments by 2100. In order to meet the growing demand, primary resource extractions are also expected to increase in the region. Environmental emissions are expected to follow suit. As with the increasing trends in energy consumption, CO_2 emission of South Asia would account for about one-fifth of world's total by 2100.

To promote economic growth in developing countries of Asia while simultaneously reducing GHG emissions that lead to global climate change requires the expanded use of clean, cost-effective technologies and practices to improve efficiency in the industrial, power, transportation, and building sectors. In addition, technologies that utilize renewable resources such as wind, solar energy, biomass, and hydropower can be particularly cost-effective in rural areas where access to electricity is limited. Use of renewable sources and energy efficiency measures can decrease consumption of fossil fuels with high GHG emissions, such as coal. In mega cities, where nearly half the world’s population lives, improved public transportation systems and urban planning can reduce energy consumption and GHG emissions from vehicles, landfills, and buildings. By encouraging policies and practices that support the widespread use of energy efficiency and renewable energy technologies at the national and local levels, the dual objectives of providing access to services while helping to mitigate global climate change can be accomplished.

10.4.6.4 Financial aspects

The financial community is awakening to the fiscal dimensions of the risk of climate change. According to the European insurer Munich Re, the annual cost of climate change related claims could reach $300 billion annually by 2050. Another major insurer, Swiss Re, no longer provides liability coverage for climate change related claims to companies that lack climate change policies. The cost of direct damage in Asia caused by tropical cyclones has increased more than 5 times in the 1980’s as compared with those in the 1970’s and about 35 times more in the early 1990’s than in 1970’s (Yoshino, 1996). In case of flood related damages, these are about 3 times and 8 times respectively in 1990s relative to those in 1980s and in 1970s. The damage caused by natural hazards has also been increasing significantly in the high GNP countries of Asia since the 1990’s. International Federation of Red Cross and Red Crescent Societies (IFRCRCS, 2004) has recently brought out a report on the magnitude of vulnerability of Asian continent (in terms of loss of human life as well as on the economy) to the natural disasters which is illustrated in **Table 10.9** below.

***Table 10.9**: Total number of people reported killed, people affected, and total amount of disaster estimated damage due to hydrometeorological (climate related extreme events) and geophysical disasters in Asia that have occurred during the past 10 year period from 1994 to 2003.*

Events	Reported disasters	People killed	People affected in 1000	Estimated damage (Million US $ at 2003 prices)
Avalanches/landslides	105	6162	2813	212
Droughts/famines	86	270923	645257	14109
Earthquakes	145	68376	32310	179997
Extreme temperatures	45	10062	893	3447
Floods	411	45961	1383083	121438
Forest/scrub fires	22	125	3056	21853
Volcanic eruptions	12	97	152	1
Windstorms	307	33270	274908	46761
Other natural disasters	10	452	47	0
Subtotal hydro – meteorological disasters	986	366955	2310056	207819
Subtotal geophysical disasters	157	68473	32463	179997
Total	1143	4,35,428	2,34,2519	3,87,817

The frequency and intensity of climate related extreme events are likely to increase in the future leading to amplified economic damages in the Asia region. The Association of British Insurers have examined the financial implications of climate change through its effects on extreme storms (hurricanes, typhoons, and windstorms) using an insurance catastrophe model (ABI, 2005). Annual insured losses from the three major storm types affecting insurance markets (hurricanes in United States, typhoons in Japan and windstorms in Europe) are projected to increase by two-thirds to US$27 billion by the 2080s. The projected increase in insured losses due to even the most extreme storms (with current return periods of 100 to 250 years) by the 2080s would be more than twice the reported losses of the 2004 typhoon season, the costliest in terms of damage during the past 100 years. The insurance industries as well as society would be adversely impacted due to extreme climatic events in Asia.

10.4.6.5 Social Vulnerability

Social vulnerability emphasizes the inequitable distribution of damages and risks amongst groups of people (Wu *et al.*, 2002). Vulnerability is a result of social processes and structure that constrain access to the resources that enable people to cope with impacts (Blaikie *et al.*, 1994). The protection from the social forces that create inequitable exposure to risk is as, or even more, important than structural protection from natural hazards (Hewitt, 1997). An approach based on social vulnerability focuses attention on the societal factors that determine the capacity to cope, response and adapt to stress, rather than the potential hazard itself. Many developing countries of Asia are rich in natural resources and have vast potential for economic development. However, these nations remain agrarian societies and are deeply susceptible to climate variability and climate change.

The rapidly urbanizing cities of Asia today present unprecedented concentrations of poverty, and in so doing mark new levels of vulnerability. Poverty is identified as the largest barrier to developing the capacity to cope and adapt (Ninh *et al*., 2005). In order to reduce social vulnerability of societies to cope with climate related disasters in developing countries of Asia, a macro-economic analyses of development programmes should be carried out while the human and physical infrastructure are enhanced. Livelihoods and income security of older persons and empowerment of marginalized groups must be ensured with better management of the expectations of the population. The life-styles, consumption patterns, family planning and equity issues are eventually shifting to the centre of the climate change debate and perhaps will provide a framework of possible solution for the poor societies in Asia.

10.5 Adaptation: Sector specific practices, options and constraints

10.5.1 Agriculture and food security

The ability of agriculture to adapt to and cope with climate change in Asia will depend on factors such as population growth, poverty and hunger, availability of arable land and water resources, farming technology and access to inputs, crop varieties adopted to local conditions, access to knowledge, infrastructure, agricultural extension services, marketing and storage systems, rural financial markets, and economic status. Vulnerable populations in developing countries of Asia have only limited capacity to protect their food production system from extreme events such as droughts and floods (FAO, 2003). The developing countries of Asia bear the brunt of the consequences of climate variability and climate change. In the short term, policy makers will need to cope with an increased risk of frequent shocks to their economies, which will affect the welfare of their most vulnerable populations. Over the long term, they will need to manage the effects of climate change on the underlying production structures of the economies.

The central challenge of sustainable agriculture is to meet the food demand of the present generation without sacrificing the needs of the future generations. This cannot be achieved without the systematic integration of the social, economic, and environmental pillars of agriculture and rural development in Asia. Sustainable agricultural development is essential for economic growth, which creates employment opportunities in non-agricultural rural sectors, which in turn reduces poverty as well. In Asia, although efforts to improve long-term productivity on small farms must be increased, emphasis must also be placed on research that will help farmers and the government cope with the expected increase in risks resulting from climate variability and climate change, and to make better use of limited water resources. Advances in seasonal climate forecasts offer considerable opportunities to improve agricultural production. Seasonal climate forecasts particularly quantitative seasonal rainfall prediction on appropriate spatial scales and the behaviour and strength of monsoon and ENSO as part of a decision support system offers great potential for sustaining agricultural production. A food security early warning system based on the seasonal climate forecasts and remote sensing technology (Sakamoto *et al*., 2005) can be expected to help build resilience to climate change and contribute positively in agricultural production through development of sustainable adaptive strategies in Asia (Tao *et al*., 2004; Tao and Yokozawa, 2005; Royal Society, 2005).

Policies that reduce pressure on resources, improve management of environmental risks, and increase the welfare of the poorest members of society can simultaneously advance sustainable development and equity, and enhance adaptive capacity and coping mechanisms. The inclusion of climate change impacts in the design and implementation of national development initiatives can reduce the vulnerability of Asian countries to climate change.

10.5.1.1 Agriculture, livestock, fisheries and aquaculture

A sizable number of studies (Parry, 2002; Droogers, 2004; Lin *et al*., 2004; Vlek *et al*., 2004 and Zalikhanov, 2004 among others) on impacts of climate change on agriculture and possible adaptation options have been published since the TAR. As system vulnerability will vary in magnitude, the ability of local populations to adapt their production systems to cope with climate change will vary across Asia. They are both controlled by the flexibility with which food provision as the supply, availability and access to food and related essential resources is mediated by government institutions and policies. More common adaptation measures than have been evaluated in above-mentioned studies are summarized in **Table 10.10** below.

Table 10.10: *Adaptation measures in Agriculture*

Sectors	Adaptation measures
Agricultural Cropping	Choice of crop and cultivar: • Use of more drought-tolerant crop varieties • Use of more disease and pest tolerant crop varieties • Use of salt- tolerant crop varieties • Introduce higher yield, earlier maturing crop varieties in cold regions Farm management: • Altered application of nutrients/fertilizer • Altered application of insecticide/pesticide • Change planting date to effectively use the prolonged growing season and irrigation practices • Develop adaptive management strategy at farm level
Livestock Production	• Breeding greater tolerance and productivity livestock • Increase stocks of forages for unfavourable time periods. • Improve Pasture and grazing management including improved grasslands and pastures. • Improve management of stocking rates and rotation of pastures • Increase the quantity of forages used to graze animals • Plant native grassland species because native species are better adapted to survival in extreme climate conditions • Increases plant coverage per hectare • Need local specific support in supplementary feed and veterinary service
Fishery	• Breeding fish to high water temperature • Fisheries management capabilities to cope with impacts of climate change must be developed
Development of Agricultural Bio-Technologies	• Development & distribution of more drought, disease, pest salt-tolerant gene into crop varieties • Develop improved processing and conservation technologies in livestock production varieties • Improve crossbreeds of high productivity animals
Improvement of Agricultural Infrastructure	• Improve pasture water supply • Improve and wide spread of irrigation systems and improve the efficiency • Improve use/store of rain and snow water • Improve information exchange system on new technologies at national as well as region and international level • Improve/develop sea defence and flood management • Equip herders, fisheries and farmers with communication system to get weather forecasts in time

It is generally recognized that adaptation measures should be an integral part of overall sustainable development plans of all the nation and region. Countries have to take necessary provisions as far as possible in their development plans to address issues such as crop and animal insurance, subsidies, water, pasture, energy pricing and many others. Moreover, many adaptation measures such as introducing new irrigation systems, protection measures against sea level rise and flood defence structures among others will be cost intensive. Such costly adaptation measure could also imply greater changes to current agricultural system. There is clearly a greater need for international, bilateral and multilateral support or investment in providing newer technology and infrastructure in many Asian countries.

Maintenance time for grassland should be settled according to the actual environmental conditions, and a reasonable rotational grazing could ensure the sustainability of grassland resources (Wang *et al.*, 2004a). Measures as increasing material input, changing the year-round grazing manner and increasing feed supply from cropping have been proposed as effective ways for maintaining and protecting the eco-environment in grasslands (Li *et al.*, 2002). Regulations of rice varietal disposition, improvement of irrigation system, double rice breeding and introducing new rice varieties could be considered as an adaptation option for avoiding decline in rice productivity due to climate change related risks (Ge *et al.*, 2002).

Many small communities in East, South and Southeast countries of Asia are highly reliant on fisheries and aquaculture, and could be greatly affected by changes in sustainable harvests induced by climate change. A conservation-oriented approach to fisheries management must consider biological and environmental factors, as well as social and economic values. Integrating fisheries and aquaculture management into coastal areas management is critical to ensure that fisheries and aquaculture needs are taken up when dealing with protection of coastal areas from sea level rise (Troadec, 2000). Analyzing aquaculture sustainability in an eco-regional context is also relevant in forecasting changes in productivity or resistance and in required related changes in culture systems, cultured species or delocalization of productive systems.

One of the important and effective adaptation measures is education and dissemination of climate change related findings at herders, fishermen and farmers level. It will be through education and awareness building with respect to environmental degradation, climate change and their possible impacts, the national governments can enhance their coping capacity.

10.5.1.2 Strategies, policies and measures for food security

In Asia, food security is one of critical issues caused by climate change. Climate change could affect food production in several ways:

- geographical shifts and yield changes in agriculture
- reduction in the quantity of water available for irrigation
- loss of land through rising sea level and the associated salinization; and
- effects on fisheries productivity through rising sea level and changes in water temperatures, currents, freshwater flows and nutrient circulation.

Hunger and malnutrition are already among the most devastating problems facing countries in Asia. The under-nutrition and malnutrition prevail in regions where environmental, economic and other factors expose the population to a high risk of impoverishment and food insecurity (FAO, 2002). Countries that currently have problems with food security would be especially vulnerable to the potential impact of climate change on food supplies.

Assessment of adaptation generates a range of strategies, policies and measures to address the potential health impacts of food security. Ideally, this list will range from interventions that are theoretically possible at some future date to those that can be implemented practically in the short term. Governments need to incorporate most of the WHO recommended nutrition guidelines concerning micronutrient deficiencies, protein and energy malnutrition or the development of food-based dietary guidelines in national nutrition policies or plans of action. There is an urgent need for developing countries of Asia to consider the impact of future climate change on malnutrition within a comprehensive national food policy.

10.5.2 Hydrology and water resources

10.5.2.1 Desertification and water scarcity

To prevent desertification and water stress, the measures such as conversion of cropland to forest (grassland), restoration and reconstruction of vegetations, improvement of the tree and herb varieties, selection and cultivation of new drought resistant varieties should be adopted. By analyzing the relationship between state of desertification and climatic change trends, the system and structure of preventing desertification should be adjusted to combine prevention of desertification with economic development. Some immediate measures, such as water saving schemes for irrigation, need to be enforced to avert the water scarcity in regions already under water stress (Wang, 2003).

Given the magnitude of projected climate change in North Asia, adaptation options to avert water scarcity include: (a) It would be necessary to (i) increase the power of recycling water supply systems and autonomous water use systems in industry sector; (ii) Use purified municipal waste waters in some industrial brunches (Frolov *et al*., 2004) and (iii) If necessary, cut water intake for industry needs during dry years; (b) Carry out measures to remove the losses of irrigation waters by increasing the efficiency of irrigation canals and systems while changes in the crop structure in favour of drought-resistant crops would be beneficial (Alcamo *et al*., 2004); (c) The power production at hydroelectric stations would have to be compensated by other (e.g. fossil fuel) power plants (Kirpichnikov *et al*., 2004); (d) Create the most favourable conditions for river fleet with depths providing the use of all available vessel types for full freight-carrying capacity during the entire navigation period – the options for optimal depths would include deepening / dredging work along the navigating channel and/or reducing the carrying capacity of ships (Golitsyn and Izrael, 2002).

Strategies for alleviating water scarcity in developing countries of Asia should include:
- joint management of surface water and groundwater, and development of comprehensive plans for future water use
- broadening the water sources and reduction in water use, and
- improvement in the synthetic utilization efficiency and strengthening the supervision so that water resource conservation law can restrict and standardize water use activity.

10.5.2.2 Water management including infrastructures

Market Based Instruments (MBIs) can play a role to foster water demand management. An important hurdle is the need to account for implementation costs, including transaction and institutional costs. Cooperation between Government, Industries and Public Utility Services can lead to a better appreciation for the need to use MBIs, and lower the implementation costs in designing and applying them. While MBIs can lead to more efficient water use or help recover costs, meeting environmental or social objectives requires other, carefully designed, policy instruments. Depending on the type of water use, and the specific location, different approaches might have to be adopted.

Technical and economic efficiency is also necessary to meet the objective of satisfying user needs and improving living conditions, as well as ensuring respect for the environment and the aquatic ecosystem. Climate change would add to the problem of water scarcity in many countries of Asia and increasing negative impact on aquatic ecosystems and groundwater resources due to excessive water abstraction. Modernization of existing irrigation schemes and demand management aimed at optimizing physical and economic efficiency in the use of natural water resources and recycled water in water stressed countries of Asia is essential. Public investment policies aimed at improving access to available water resources should also be based on integrated water management, respect for the environment and as an important element promote better practices for wise use of water in agriculture, including recycled waste water. Scenarios for future development e.g. in the areas of irrigation, drought management, desalination, urban needs and tourism must be prepared in developing countries of Asia.

10.5.2.3 Recycling, reuse and conservation technologies

Reducing fresh water requirements through conservation technologies and reclamation / recycling / reuse strategies is a core element of a sustainable adaptation initiative in Asia. Water recycling has proven to be effective and successful in creating a new and reliable water supply, while not compromising public health. Recycled water can satisfy most water demands, such as agriculture, landscape and public parks irrigation and other applications. Non-potable reuse of water will continue to grow in most water stressed countries of Asia. However, in many countries of Asia, the use of recycled water through adaptation of advances in wastewater treatment technology would need to expand in order to accommodate the growing water supply demands.

As an adaptation measure, apart from meeting non-potable water demands, recycled water can be used for recharging ground water aquifers and augmenting surface water reservoirs. Recycled water can also be used to create or enhance wetlands and riparian habitats. While water recycling is a sustainable approach towards adaptation to climate change and can be cost-effective in the long term, the treatment of wastewater for reuse such as that being practiced in Singapore now and the installation of distribution systems can be initially expensive compared to such water supply alternatives as imported water or ground water but are potentially important adaptive options in many countries of Asia. Institutional barriers, as well as varying agency priorities, can make it difficult to implement water recycling and wastewater reuse projects. But as water demands grow and environmental needs become compelling, water recycling will have to play a greater role in our overall water supply. By working together to overcome obstacles, water recycling and wastewater reuse, along with application of water conservation technologies, can help many Asian countries to conserve and sustainably manage its vital water resources when water stress becomes more severe due to climate change in future.

10.5.3 Coastal and low lying areas

10.5.3.1 Infrastructure

The response to sea level rise could mean protection, accommodation and retreat. As substantial socio-economic activities and population are currently highly concentrated in the coastal zones in Asia, protection should remain as key focus area in Asia. Coastal protection constructions in Asia for 5-year to 1000-year storm surge elevations need to be considered. Most mega cities of Asia located in coastal zones need to ensure that future constructions are done at elevated levels (Nishioka and Harasawa, 1998; Du and Zhang, 2000; Nicholls, 2004). The dike heightening and strengthening has been identified as one of the adaptation measure for coastal protection (Du and Zhang, 2000; Huang and Xie, 2000; Li *et al*., 2004a, b).

10.5.3.2 Integrated coastal zone management

Integrated Coastal Zone Management (ICZM) provides an effective coastal protection strategy to maximize the benefits provided by the coastal zone and to minimize the conflicts and harmful effects of activities on social, cultural and environmental resources to promote sustainable management of coastal zones (World Bank, 2002). ICZM concept is being embraced as a central organizing concept in the management of fishery, coral reef, pollution, mega cities and individual coastal systems in China, India, Indonesia, Japan, Korea, Philippine, Vietnam and Kuwait. It has been successfully applied for prevention and control of marine pollution in Philippines and China over the past few years. The ICZM concept and principle may be adopted for coastal prevention and management in other countries of Asia.

10.5.4 Natural systems and biodiversity

10.5.4.1 Sustainable forest management

Because plantations are generally highly managed, adaptations to changes in climate and atmospheric composition are feasible, including species substitutions and shortening rotations. The probability of significant adverse impacts of climate change on Asian forests is high in the next few decades (Isaev *et al*., 2004). More frequent extreme weather events are also likely to have negative impacts on Siberian forests. The relevant plantation technology should be used in development of concrete forestry adaptation options as well as in choice of locations for reforestation projects. The prevention of fire disaster must be strengthened, and forest insect disease prevention and management should be carried out to protect forest resources and facilitate natural environment for sustainable development.

As much of the deforestation and forest degradation in Asia has been caused by the expansion and degradation of arable and grazing lands and subsistence and commodity demand for wood products, programmes to reduce deforestation and degradation must be accompanied by measures that increase agricultural productivity and sustainability. In recent years, there has been significant expansion of "protected areas" into areas of both mature and secondary forests for conservation of biodiversity and sustainable timber production in some countries of Asia. It is likely that the trend towards management of forests for sustainable timber production will increase in the future. Adaptation and mitigation measures to climate change include extending rotation cycles, reducing damage to remaining trees, reducing logging waste, implementing soil conservation practices, and using wood in a more C-efficient way such that a large fraction of their C is conserved. The *storage management* must be practiced to increase the amount of C in vegetation and soil of forests by increasing the area and/or biomass C of natural and plantation forests, and to increase storage in durable wood products through protecting secondary forests and other degraded forests and through establishing plantations on non-forested lands, promoting natural or assisted regeneration in secondary forests followed by protection, or increasing tree cover on agricultural or pasture lands through agroforestry. Sequestering C by storage management is only a short-term option and this necessitates *Substitution management* option to increase the transfer of forest biomass C into products (e.g., construction materials and biofuels) rather than using fossil-fuel-based energy and products and cement-based products. Substitution management involves expanding the use of forests for wood products and fuels obtained either from establishing new forests or plantations, or increasing the growth of existing forests through silvicultural treatments and has the greatest mitigation potential in the long term (>50 years).

10.5.4.2 Biodiversity conservation

The factors that are most directly implicated in changes in biodiversity, namely, habitat conversion, exploitation of wild resources, and the impacts of introduced species will continue to exert major influences during the 21st century, although their relative importance will vary regionally and across biomes. Deforestation pressure will remain high in the immediate future in a number of developing countries of Asia, including those such as Indonesia and the Philippines, which hold many endemic forest-dependent species, often with small ranges. In combination, they will ensure continuing biodiversity loss in Asia, as expressed through declines in populations of wild species and reduction in area of wild habitats. Marine ecosystems, particularly in coastal regions of East, South and Southeast Asia, will also continue to contend with a wide range of pressures, including siltation and eutrophication from land runoff, coastal development, conversion for aquaculture, and impacts of climate change (Groombridge and Jenkins, 2002). The forest cover may increase in some regions of North Asia, because growing urbanization will lead to the abandonment of marginally productive lands allowing reversion to a more natural state. Boreal forest cover should continue to increase, or at least stabilize, and many forest species will thrive, although with changes in distribution and relative abundance as a result of climate change. However, uncontrolled and frequent fires will mean that abandoned lands in many areas will remain relatively degraded.

10.5.5 Human health

Malaria and dengue fever are among the most important vector-borne diseases in parts of Asia. Encephalitis is also becoming a public health concern. Unprecedented population growth, increased human mobility and lack of mosquito control have contributed to epidemic activity. Health risks due to climatic changes will differ between countries of Asia depending upon the infrastructure availability. Human settlement patterns in the different regions of Asia will influence disease trends. Climatic anomalies such as floods and droughts associated with ENSO and the resulting detectable influence on marine and terrestrial pathogens, including coral diseases, oyster pathogens, crop pathogens, Rift Valley fever and human cholera in Asia could have far-reaching consequences on all life-support systems. It is therefore a factor that should be placed high among those that affect human health and survival.

Assessment of the impact of climate change is the first step for exploring adaptation strategy. The disease monitoring system is essential as the basic data source. Specifically, the monitoring of diseases along with related ecological factors is required because the relation between weather factors and vector-borne diseases are complicated and delicate (Kovats *et al*., 2003). Also, disease monitoring is necessary in assessing the effectiveness and efficiency of the adaptation measures (Wilkinson *et al*., 2003). For effective adaptation measures, the potential impacts of climate variability and change on human health must be identified, along with barriers to successful adaptation and the means of overcoming such barriers.

10.5.6 Human dimensions

10.5.6.1 Disasters and migration management

The importance of ecosystems, like forests, wetlands, estuaries and marine environments, should not be underestimated in relation to their capacity to absorb the impacts of natural disasters. For example, overgrazing and logging on steep slopes of upland sections in watersheds may cause increased levels of erosion, which can result in landslides upstream, and increased flooding downstream. Practices like agro-forestry, soil conservation measures and limited and controlled logging serve to reduce disasters. The safety standards of disaster prevention projects for rivers, lakes, sea ponds and shore lines should be properly enhanced. Based on potential impacts of climate change on projects, the adaptive measures for climate change such as early warning and forecasting system, emergency response system, sharing platform of disaster information services, should be adopted.

Asian countries are at different stages of institutional development with respect to disaster reduction. Some, such as Japan, have a long-established system of disaster management. Stimulated by the International Decade for Natural Disaster Reduction (IDNDR), other countries have either strengthened existing frameworks or are formulating new ones. Appropriate measures and actions still remain to be taken at the regional and national levels to reduce risks and losses due to disasters.

Rapid population growth, urbanization and weak land-use planning are some of the reasons why poor people move to fragile and high risk areas which are more exposed to natural hazards. Moreover, the rapid growth of industries in urban areas has induced rural–urban migration. Rural development together with networking and advocacy, and building alliances among communities is a prerequisite for reducing the migration of people to cities and coastal areas in most developing countries of Asia (Kelly and Adger, 2000). Raising awareness about the dangers of natural disasters including those due to climate extremes is also crucial among the governments and people so that mitigation and preparedness measures could be strengthened.

10.5.6.2 Institutional innovation and financial investment

Financial institutions have begun dealing in “climate derivatives” to compensate enterprises for loss due to extreme weather events. Such events have a large impact on the medium scale enterprises, the travel and tourism industries, and ski area and lodge operators. To minimize climate related risk, an insurance system using market mechanisms is being investigated by industry as an adaptive measure. A serious impact on the ski industry could be anticipated due to global warming. In the areas where the snow conditions would seriously deteriorate, planning should begin on the development of new industries more resistant to or suited to a warmer atmosphere, thus avoiding excessive reliance on the ski industry. New leisure industries, e.g., grass-skiing, hiking, residential lodging, eco-tourism could be considered to compensate for the income decrease due to snow deterioration (Fukushima *et al*., 2002).

With the manifestation of legitimate and credible emissions rules, some firms with access to new technologies may emerge relatively quickly. Fuel industries continue to shift the balance of their business in favour of lower carbon energy sources and in particular natural gas. The aluminium producers are poised to benefit from the auto industry's adoption of aluminium to create fuel-efficient vehicles with better strength-to-weight ratios that produce lower emissions. Aluminium’s use in vehicles is rapidly increasing due to a heightened need for fuel efficient, environmentally friendly vehicles. Companies that produce new generation diesel engines may turn out to be the big winners. With advanced fuels there are next-to-no traditional air pollutants, making diesel engines amazingly efficient.

10.5.6.3 Urban planning and development

The risks of heat stress are most pronounced in large cities due to urban heat island effect in summer. Planners should be aware of the health relevance of the urban climate and how innovative planning could improve the health of those living there. Appropriate urban planning should have the following objectives:

• reducing the heat island in summer
• reducing the heat load on buildings
• diminishing the problem of high night-time indoor temperature; and
• taking climate change into account in planning new districts and buildings and in setting up new regulations on building and urban development.

Several measures can be taken to reduce the heat load to which an individual is exposed in a city, such as planting trees or building houses with arcades that provide shade. Planners should therefore consider allowing cool air from the surroundings to penetrate the dwelling units at night by maintaining ventilation paths (Shimoda, 2003). The passive cooling technologies, which maintain indoor thermal comfort without air-conditioners or which reduce the cooling load, including reflective surfaces, the control of solar radiation by vegetation and blinds, earth tubes, the formation of air paths for natural ventilation, and rooftop planting should be promoted.

As number of room air-conditioners and its operating hours continue to increase in metros of most countries in Asia, energy efficiency of room air-conditioners including more effective thermal insulation is critical from both the viewpoint of mitigation/adaptation to climate change. Adaptation of life style such as noon recess extending to 2 hours and use of light clothes to acclimatize during summer in major urban centres of Asia could be an important measure for energy saving and safeguard against ill-health by reducing the incidence rate of heat stroke. In drier outdoor environment, humidification of spaces outside buildings by planting and fountains might be useful from the viewpoints of health, fire prevention and static electricity prevention.

Secondary and tertiary impacts arising from changes in individual and social behaviour (a demand structure that cannot be projected and securing supply stability for that unknown demand) due to warming need to be assessed. A long-term strategy is to establish scenarios for occurrence of irreversible extremes (quality, quantity, probability, etc.), and to assess if the present systems can withstand these extreme changes and the associated risk factors.

10.5.7 Key constraints

Due to the specific natural and social economic conditions of Asia, the key constraints for adaptation to climate change and climate variability come mainly from three aspects. Firstly, the natural constraints include diversified/complicated natural conditions, frequent extreme weather/climate events, and fragile environmental conditions/background, which becomes more complex due to climate change and climate variability in Asia, and results in larger spatial and temporal differences. The second aspect is socioeconomic constraints. Lower economic development level in Asia causes constraints for adaptation to climate change and climate vulnerability. At the same time, inequality to access resources makes the constraints more seriously. The constraints include lack of knowledge on interconnections between adaptation and mitigation options and insufficient knowledge to identify positive and negative impacts of climate change. For example, climate change could have some beneficial impacts for the cold regions such as North Asia and North East China. Lack of knowledge also includes weak public awareness and lag of scientific lore. Future impacts of climate change have not been assessed with precise accuracy in some regions and sectors. Lower economic development level in Asia also produces constraints of lower adaptive capacity and lower social welfare, such as insufficient investment in infrastructure and not enough investment in technology development. Lack of appropriate policy approaches also limit the response options. At the moment, in Asian countries, there are few specific policies for climate change adaptation, which results in lack of flexible adaptation processes and comprehensive adaptation. Many other policy issues currently prevent the policymakers and the public to think about adaptation.

10.6 Case Studies

10.6.1 Mega deltas in Asia

In Asia, rivers surrounding the Tibetan Plateau contribute ~50% of the world's total river-borne sediments to the ocean and 11 mega deltas with an area greater than 10,000 km^2 are formed in the coastal zone of Asia which are located in different climate zones (**Table 10.11**). These mega-deltas are usually populous except the Lena delta in North Asia. Six mega cities in Asian delta region will have population exceeding 10 millions by 2010, covering 46% of the Asia's total (Nicholls, 1995). The deltas are also usually economically more developed. For instance, GDP of the Changjiang delta in 2003 is 19.5% of the China's total and the GDP of the three metropolitans located in the Zhujiang delta, Changjiang delta and Huanghe delta will represent 80% of China's total GDP in 2050 (Jiang *et al*., 2002; She, 2004).

Table 10.11: *Mega Deltas of Asia*

Features	Lena	Huanghe	Changjiang	Zhujiang	Red River	Mekong	Chao Phraya	Irrawaddy	Ganges-Brahmaputra	Indus	Shatt-Arab
Area (x10^3 km^2)	43.6	36.3	66.9	10	16	62.5	18	20.6	100	29.5	18.5
Water Discharge (10^9 m^3/yr)	520	33.5	924	326	120	470	30	430	1330	185	46
Sediment load (10^6t/a)	18	849	486	76	130	160	11	260	1969	400	100
Climate zone	Boreal	Temperate	Temperate	temperate	Tropical	Tropical	Tropical	Tropical	Tropical	Semi-arid	Arid
SLR (cm) in 2050	10-90(2100)	70-90	50-70	40-60						20-50	
Ground subsidence (m)	no	2.6-2.8	2.0-2.6	no			0.2-1.6		0,6-1.9mm/a		
Population (x10^6)		24.9(00)	76(03)	42.3(03)	14.8(03)	12.5(03)	18.5(03)	3.5	143	1.5	
GDP ($\$10^9$US)		58.8(00)	274.4(03)	240.8(03)							
Mega-city	no	Tianjin	Shanghai	Guangzhou			Bangkok		Dhaka	Karachi	
Coastal protection	no	1/20-1/50	1/50-1/1000	1/20-1/100	Protected	Protected	Protected	Protected	Protection		Protection
Wetland loss($10^3$$km^2$)		0.735							4.29	1.595	6.699
Mangroves ($10^3$$km^2$)	no	no	no	no				4.2	10	1.6	no
Saltwater intrusion(km)			100		30-50	60-70			100	80	
Coastal erosion(m)	3.6-4.5/a					10-15	30-50				
Delta growth (km^2/a)		DG-21km^2/a	DG-16km^2/a	DG-11km^2/a				PD50-60/a	DG-5.1km^2/a	PD30/a	
Natural hazards			TC	TC,FD	TC,FD				TC,FD	TC,SWI	
Inundated area($10^3$$km^2$)by SLR		21.3(0.3m)	54.5(0.3m)	5.5(0.3m)	5(1m)	20(1m)					

PD - Progradation of coast; TC - Tropical cyclone; FD - Flooding;
SWI - Saltwater intrusion DG - Delta growth in area

The ecosystems in the mega delta wetlands are various depending on climatic zones where they are located. The wetland in the Lena delta is covered by the polar desert and Tundra vegetation dominated by low growing woody shrubs (ACIA, 2004). Wetlands in deltas of the temperate climatic zone are characterized by reed and salt-marsh grasses. In the wetlands of the deltas in South and Southeast Asia, mangrove forests are usually present and their types vary with climate conditions. For instance, in the Indus delta the largest arid-climate mangrove forests in the world (1600 $km^{2)}$ are found (IUCN, 2003) whereas wetlands in the Shatt Al-Arab delta are covered by widespread Sabkha, with crusts of sodium chloride and gypsum owing to arid climate and high salinity in the Persian Gulf (Coleman, 2004; Chiffings, 2004).

The mega deltas of Asia are vulnerable to climate change and sea-level rise, reclamation for agriculture, industrial and infrastructural purposes, and alteration of stream flows usually by impounding of water. The Lena delta located in the boreal zone has been retreating at a rate of 3.6-4.5 meter per year due to thermo-erosion associated with rise in temperature (Leont'yev, 2004). On the other hand, most of the mega-deltas fed by rivers originating from Tibetan Plateau are facing local erosion due to sediment starvation. Coastal erosion and inundation in the Huanghe Delta has significantly increased due to cyclones and frontal systems. Many of Asian deltas are subjected to inundation due to storm surges and floods from river drainage, such as the Deltas of the Zhujiang, the Red-River, the Ganges-Brahmaputra (Tuan and Molle, 2003; Nicholls, 2004). The Indus Delta has eroded as a result of reduced water discharge (from 185×10^9 m^3 to 12.3×10^9 m^3) *during what period?* due mainly to upstream water impoundment that leads to flow interruption for 100-200 days per year and also due to substantial saltwater intrusion in the delta (Inam *et al*., 2003). The saltwater intrusion deteriorates mangrove forests and decreases its diversity, and reduces agriculture production and freshwater fish catch, resulting in the economic loss of US$125x 10^6 per annum (IUCN, 2003).

Most Asian mega deltas are extensively reclaimed due to urbanization and expansion of agricultural areas. Reclamation usually destroys the natural ecosystems in mega-deltas but in turn it lends stability and protection to mega deltas against erosion from sea waves and sea level rise. The sustainability of mega deltas in Asia in a warmer climate will rest heavily on policies and programs that promote integrated and coordinated development of the mega deltas and upstream areas, balanced use and development of mega deltas for conservation and production goals, and comprehensive protection against erosion from river flow anomalies and seawater actions.

10.6.2 The Himalayan Glaciers

Himalayan glaciers cover about three million hectares or 17% of the mountain area as compared to 2.2% in the Swiss Alps. They form the largest body of ice outside the Polar caps and are the source of water for the innumerable rivers that flow across the Indo-Gangetic plains. Himalayan glacial snowfields store about 12,000 km^3 of freshwater. About 15,000 Himalayan glaciers form a unique reservoir which supports perennial rivers such as the Indus, Ganga and Brahmaputra which, in turn, are the lifeline of millions of people. The Gangetic basin alone is home to 500 million people, about 10% of the total human population.

Glaciers in the Himalaya are receding faster than in any other part of the world (see **Table 10.12** below) and, if the present rate continues, the likelihood of them disappearing by the year 2035 and perhaps sooner is very high if the Earth keeps getting warmer at the current rate. The glaciers will be decaying at rapid, catastrophic rates. Its total area will shrink from the present 500,000 to 100,000 km^2 by the year 2035.

Table 10.12: *Record of retreat of some glaciers in the Himalaya*

Glacier	Period	Retreat of Snout (meter)	Average Retreat of Glacier (meter/year)
Triloknath Glacier (Himachal Pradesh)	1969-1995	400	15.4
Pindari Glacier (Uttaranchal)	1845-1966	2840	135.2
Milam Glacier (Uttaranchal)	1909-1984	990	13.2
Ponting Glacier (Uttaranchal)	1906-1957	262	5.1
Chota Shigri Glacier (Himachal Pradesh)	1986-1995	60	6.7
Bara Shigri Glacier (Himachal Pradesh)	1977-1995	650	36.1
Gangotri Glacier (Uttaranchal)	1977-1990	364	28.0
Gangotri Glacier (Uttaranchal)	1985-2001	368	23.0
Zemu Glacier (Sikkim)	1977-1984	194	27.7

The receding and thinning of Himalayan glaciers can be blamed primarily on the global warming due to increase in anthropogenic emission of greenhouse gases. The relatively high population density near these glaciers and consequent deforestation and land use changes has also affected adversely these glaciers. The five-kilometre-long Dokriani Bamak glacier in Himachal Pradesh that feeds the Ganges retreated by 20 m in 1998 in spite of a severe winter in 1997, compared to an annual average of 16.5 m over the past five years. This is a phenomenal melt rate. The 30.2 km long Gangotri glacier, too, has been receding alarmingly in recent years. From observations dating back to 1842, the rate of recession of the snout — the point at which the glacier ice ends — has been found to increase more than two-and-a-half fold per year (**Fig. 10.6**). Between 1842 and 1935, the glacier was receding at an average of 7.3 m every year, whereas between 1935 and 1990, the rate of recession has gone up to 18 m a year. The average rate of recession between 1985 and 2001 is about 23 m per year (Hasnain, 2002).

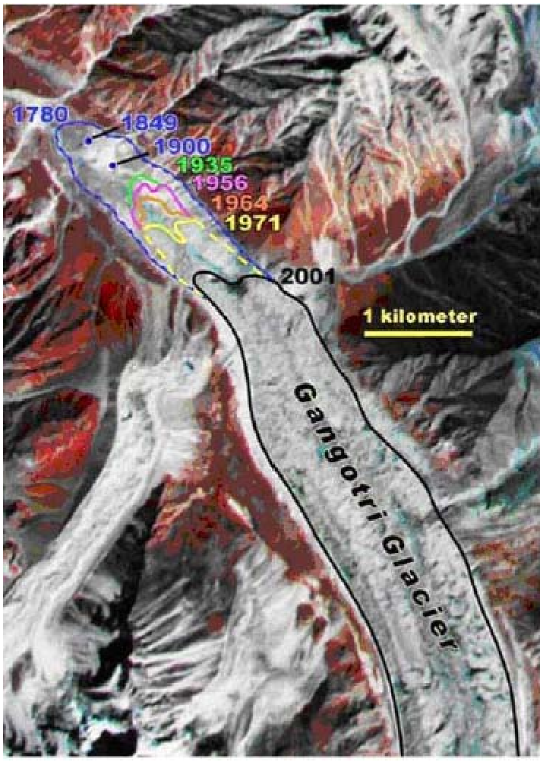


Fig. 10.6 *This composite image from the ASTER (advance space Borne Thermal Emission and Reflection Radiometer) instrument aboard NASA's terra satellite shows how the Gangotri Glacier Terminus has retracted since 1780 (courtesy of NASA EROS Data Center, Sep 9, 2001).*

Most of the rivers in northern India originate from glaciers. About 70 to 80% of the water in these rivers comes from snow and glacial melts, and the rest from monsoonal rains. Does this mean that the Ganga, Indus, Brahmaputra and the innumerable rivers that criss-cross the entire northern Indian plain will become seasonal rivers in the near future as a consequence of climate change?

10.7 Sustainable development challenges

Sustainable development represents a compromise between the twin goals of environmental sustainability and human economic development and suggests that these are compatible, attainable and mutually inseparable. It implies a development that drives a country's economy within the limited ability of its ecosystem to regenerate resources extracted from it for economic growth and to absorb and clean up the wastes given off by the economy that are otherwise harmful within and outside its boundary. Thus sustainable development is commonly evaluated not only in terms of social well being and intra and inter-generational equity but also in terms of environmental quality. As the socioeconomic development level is relatively low in most countries of Asia, improvements in the socioeconomic condition can strongly support to solve the environmental issues (including climate change and its adaptation). Some of the key issues and challenges related to sustainable development in Asia and its impacts on the environment include:

- poverty and illiteracy
- effective protection of environment
- prudent use of natural resources
- maintaining higher level of economic growth and equitable development
- role of ICT in socioeconomic growth
- people empowerment; and
- compliance with and Governance of MEAs.

The discussion below will focus on how the above issues and challenges moderate the main drivers of environmental change (e.g., climate change, land use and land cover change, and institutional change) in Asia and support sustainable development pathways for the future.

10.7.1 Poverty and illiteracy

Majority of the Asian population are living below the poverty threshold. Coupled with illiteracy, poverty subverts the ability of the people to pursue the usually long term sustainable development goals in favour of the immediate goal of meeting their daily subsistence needs. This manifests in the way poverty drives poor communities to abusive use of land and other resources that lead to onsite degradation and usually macro scale environmental deterioration. In the absence of opportunities for engaging in stable and gainful livelihood, poverty stricken communities are left with no option but to utilize even the unproductive lands or lands that have been legally set aside for protection purposes such as conservation of biodiversity, soil and water.

10.7.2 Economic growth and equitable development

A key concern in most Asian countries is how to propel their economies to a rate of growth that will pull its poor up to alleviate the poverty where they are expected to more likely appreciate the need to protect the environment. Such concerns become more challenging when the baseline is saddled with inequitable opportunities to the disadvantage of the poor. The mere growth in economy is insufficient to achieve sustainable development goals particularly environmental protection. As the economy grows there is a need to increase the investment on enhancing the ability of the poor to appreciate and actively participate in economic development as well as in the protection of the environment. This will include investing in building up the technical and financial readiness of the poor through training and suitable financial assistance programs.

10.7.3 ICT and socioeconomic growth

Information and Communication Technology (ICT) has become a potent force in social, economic, and political life. The ICTs have a powerful role for Natural Resources Data Management System with a focus on development of spatial data management tools for local level planning for water resource management, land use planning, energy management and infrastructure development. However, the impact of ICT development oriented programme can probably be judged only if it serves as a mediator of social, political and economic functions. Any development process has to ensure that it plays a transformative role for social inclusion of the marginalized sections. ICT can play a critical role in providing an enabling environment for local development and people's empowerment. ICT can provide employment opportunities; improve people's access to basic services, creating networks for disaster management, information sharing, knowledge building and increasing transparency and accountability and effectiveness of development actors. Developing Countries in Asia need to embrace ICT at both the policy and strategy levels and also with supporting bottom-up approaches that can help to ensure that national strategies are responsive, demand-driven and contribute to overall socioeconomic growth. ICT could be mainstreamed into areas such as poverty reduction, governance, decentralization, gender equity, environmental sustainability, disaster preparedness, vulnerability reduction and adaptation to climate change through synergistic partnerships in favour of the poor and marginalized.

10.7.4 Compliance with and governance of MEAs

Multilateral environmental agreements (MEAs) are critical to the attainment of sustainable development goals in Asia. Common problem areas in Asia (i.e., biodiversity conservation and forest utilization, climate change, international water resources, overexploitation of regional fisheries, trans-boundary air pollution, and pollution of regional seas) related to sustainable development are being dealt with through several MEAs. Some of these agreements include the Framework Convention on Climate Change (FCCC), the Convention on Biological Diversity (CBD), the Convention to Combat Desertification (CCD), the Convention on International Trade in Endangered Fauna and Flora (CITES), the Ramsar Convention to protect Mangroves and Wetlands, the Montreal and Kyoto Protocols to address problems of the breakdown in the Earth's protective ozone layer and global warming, ITTO that governs the exploitation of tropical forests and conservation of biodiversity and International Convention for the Prevention of Pollution from Ships for control of pollution of Regional Seas. The major challenge for Asian countries is how to promote the adherence to and compliance with the terms and conditions of MEAs among the participating countries without unduly hampering economic development. It will require strong mechanism for monitoring the efforts of each country to implement the provisions of these agreements.

10.7.5 Prudent use of natural resources

Inherent to the concept of sustainable development is the inseparability of natural resource use and environmental protection. Thus, sustainable development pathways must employ a package of resource utilization strategies that maximize outputs and minimize wastes and damages to the ecosystems, and protection measures that complete the shield of the ecosystems against injurious agents independent of resource utilization. The challenge for most of Asia will fall greatly on countries with developing economies where the need to maximize production could outweigh the necessity to protect the ecosystems and the environment in future.

10.8 Key uncertainties, research gaps and priorities

10.8.1 Uncertainties

The time lags between identifying the nature of the problems, understanding them, prescribing remedies, and implementing them are long. Waiting for relative certainty about the nature of climate change before taking actions to reduce climate change related risks might prove far more costly than taking certain proactive management and planning steps now. Methods must be used that explicitly incorporate uncertainty into the decision process.

The base for future climate change studies is designing future social development scenarios by various models and projecting future regional and local changes in climate and its variability based on those social development scenarios so that most plausible impacts of climate change could be assessed. The emission scenarios of greenhouse gases and aerosols are strongly related to the socioeconomics of the countries in the region and could be strongly dependent on development pathways followed by individual nations. Inaccurate description on future scenarios of socioeconomic change, environmental change, land use change and technical advancement will lead to incorrect GHG emission scenarios. Future impacts of technological progress and social development on the natural system also contribute to uncertainties in assessing the impacts of climate change. Therefore factors affecting design of social development scenarios need to be examined to identify key uncertainties.

The large natural climate variability in Asia adds a further level of uncertainty in the evaluation of a climate change simulation. Our current understanding of the precise magnitude of climate change due to anthropogenic factors is relatively low due to imperfect knowledge and/or representation of physical processes, limitations due to the numerical approximation of the model's equations, simplifications and assumptions in the models and/or approaches, internal model variability, and inter-model or inter-method differences in the simulation of climate response to given forcing. Current efforts on climate variability and climate change studies increasingly rely upon diurnal, seasonal, latitudinal, and vertical patterns of temperature trends to provide evidence for anthropogenic signatures. Such approaches require increasingly detailed understanding of the spatial variability of all forcing mechanisms and their connections to global, hemispheric, and regional responses. Since the anthropogenic aerosol burden in the troposphere would have large spatial and temporal variations in the atmosphere, its future impact on regional scale would be in striking contrast to impacts from greenhouse gases. Considerable uncertainty still prevails about the indirect effect of aerosols on tropospheric clouds, which could strongly modulate the climate. Accurate projections of future regional climate change, therefore, remain a challenge.

Uncertainty in assessment methodologies *per se* is also one of main source of uncertainty. In the model based assessments, results on impacts of climate change, in fact, accumulate errors from the methodologies for establishment of socioeconomic scenarios, environmental scenarios, climate scenarios, and climate impact assessment. A small error may be enlarged in the process of such accumulation.

Inadequate studies on interaction in sectors cause incomplete consideration on climate impact assessment. Most of the recent model based assessments focus on impacts of climatic elements, such as surface temperature, precipitation and CO_2 level, on single system (agriculture, water resources etc.). Indirect impacts of climate change or interaction between sectors, e.g. impact of water resources on agricultural development under climate change scenarios, are seldom considered. Progress in technology and change of policies are also not appropriately accounted for. Therefore, such assessments cannot truly represent non-linear response of the sectors to climate change.

10.8.2 Confidence levels

The vulnerability of key sectors to the projected climate change for each of the six subregions of Asia based on currently available scientific literature referred to in this assessment have been assigned a degree of confidence which is listed in **Table 10.13** below. The availability of water resources, food productivity and biodiversity in most of the subregions of Asia would be highly vulnerable to climate change. The potential impacts of climate change would be felt most severely in East, South and Southeast Asia. There may be some beneficial impacts of climate change in North Asia.

Table 10.13*: Vulnerability of key sectors to the impacts of climate change by subregions in Asia*

Sub-regions	Food and Fibre	Bio-diversity	Water Resource	Coastal Ecosystem	Human Health	Settlements	Land Degradation
North Asia	+1 / H	-2 / M	+1 / M	-1 / M	-1 / M	-1 / M	-1 / M
Central Asia	-2 / H	-1 / M	-2 / VH	-1 / L	-2 / M	-1 / M	-2 / H
Tibetan Plateau	+1/ L	-2 / M	-1 / M	Not applicable	No information	No information	-1 / L
East Asia	-2 / VH	-2 / H	-2 / H	-2 / H	-1 / H	-1 / H	-2 / H
South Asia	-2 / H	-2 / H	-2 / H	-2 / H	-2 / M	-1 / M	-2 / H
Southeast Asia	-2 / H	-2 / H	-1 / H	-2 / H	-2 / H	-1 / M	-2 / H

Vulnerability:
-2 – Highly Vulnerable
-1 – Moderately Vulnerable
0 – Slightly or Not Vulnerable
+1 – Moderately Resilient
+2 – Most Resilient

Level of Confidence:
VH - Very High
H - High
M - Medium
L - Low
VL - Very Low

10.8.3 Unknowns

Some of the greatest concerns emerge not from the most likely future outcomes but rather from possible "surprises". Growing evidence suggests the ocean-atmosphere system that controls the world’s climate can lurch from one state to another such as a shutdown of the ‘ocean conveyor belt’ in less than a decade. Due to the complexity of Earth Systems, it is possible that climate change will evolve quite differently from what we expect. Certain threshold events may become more probable and non-linear changes and surprises should be anticipated, even if they cannot be predicted with a high degree of confidence. Abrupt or unexpected changes pose great challenges to our ability to adapt and can thus increase our vulnerability to significant impacts.

The spotlight in climate research is shifting from gradual to rapid or abrupt change. There is some risk that a catastrophic collapse of the ice sheet could occur over a couple of centuries if polar water temperatures warm by a few degrees. Scientists suggest that such a risk has a probability of between 1 and 5% (Alley, 2002). Because of this risk, as well as the possibility of a larger than expected melting of the Greenland Ice Sheet, a recent study estimated that there is a 1% chance that global sea level could rise by more than 4 meters in the next two centuries (Hulbe and Payne, 2001).

10.8.4 Research gaps and priorities

In general, the level of social-economic development of countries and regions in Asia is relatively low. The current understanding of science and state of available technology cannot satisfy the requirements of global change research. A number of fundamental scientific questions relating to the build-up of greenhouse gases in the atmosphere and the behaviour of the climate system need to be critically addressed which include (a) the future usage of fossil fuels, (b) the future emissions of methane, (c) the fraction of the future fossil-fuel carbon that will remain in the atmosphere and provide radiative forcing versus exchange with the oceans or net exchange with the land biosphere, (d) details of the regional and local climate change given an overall level of global climate change, (e) the nature and causes of the natural variability of climate and its interactions with forced changes, and (f) the direct and indirect effects of the changing distributions of aerosols.

An effective strategy for advancing the understanding of adverse impacts of climate change in Asia will require strengthening the academic and research institutions to make an all-out effort to conduct innovative research at the regional or sectoral level that also promotes analysis of the response of human and natural systems to multiple stresses. Research enterprises dealing with climate change and the interactions of human society with the environment must also be enhanced.

Priorities for Asia in its quest for understanding the regional, national and local sector specific impacts of climate change and drawing up appropriate adaptation / mitigation strategies are:

- basic physiological and ecological studies of the effects of changes in atmospheric conditions. The most pressing need over much of the region is for sound assessment and monitoring programs to establish current baselines and identify rates of change
- capability to establish systematic observation facilities and collection and compilation of basic data
- impacts of extreme weather events such as disasters from flood, surges storm, sea level rising, and plant diseases and insect pests
- adaptation researches including agro-technology, water resources management, integrated coastal zone management; pathology and diseases monitoring and control
- sectoral interaction in irrigation and water resources, agricultural land use and natural ecosystem, water resources and cropping, water resources and livestock farming, water resources and aquaculture, water resource and hydropower, sea level rise and land use, sea water invasion and land degradation; and
- identification of the critical climate thresholds for various regions and sectors to better understand the response of different systems to climate change.

In addition to the above priorities, there is need for strengthening existing cooperation among countries in Asia as also among global partners in respect of (a) improvement of information-sharing and data networking on climate change in the region, (b) collection and sharing the knowledge on climate change and its ecological, social and economical impacts in the region, and (c) developing approaches and methodology for cost-effective adaptation and mitigation strategies to minimise the impacts of climate change in the region.

References

ABI (Association of British Insurers), 2005: Financial Risks of Climate Change, Summary Report, 40pp.

ACIA (Arctic Climate Impact Assessment), 2004: *Impacts of a Warming Arctic* – Synthesis report of the Arctic Climate Impact Assessment, Policy Document prepared by the Arctic Council and presented at the Fourth Arctic Council Ministerial Meeting, Reykjavik, 24 November 2004, 140pp.

ADB (Asia Development Bank), 1994: Climate Change in Asia: Vietnam Country Report - Manila, Asia Development Bank, 103pp.

Agarwal, P. K., S.K. Bandyopadhyay, H. Pathak, N. Kalra, S. Chander and S. Kumar, 2000: Analysis of yield trends of the rice-wheat system in north-western India, Outlook on Agriculture, 29(4), 259-268.

Akhtar, R., and A. J. McMichael, 1996: Rainfall and malaria outbreaks in western Rajasthan: Lancet, 348, 1457-1458.

Alcamo, J., Dronin N., Endejan M., Golubev G., Kirilenko A., 2004: A new perspective on the impacts of climate change on Russian agriculture and water resources, In Proceedings of World Climate Change Conference, 29 September – 3 October, 2003, Moscow, pp.324-335.

Ali, A., 1999: Climate change impacts and adaptation assessment in Bangladesh. In: Mimura, N. (ed.) National assessment results of climate change: impacts and responses. Climate Research, Special 6, 109-116.

Alley, R. B., 2002: Climate Change: Enhanced: On Thickening Ice?, *Science* 2002 295: 451-452.

Allison, M.A., 1998: Historic changes in the Ganges-Brahmaputra Delta Front. Journal of Coastal Research, 14 (4), 1269-1275

Allison, M.A., S.R. Kham, S.L. Goodbred Jr. and S.A. Kuehl, 2003: Stratigraphic evolution of the late Holocence Ganges-Brahmaputra lower delta plain. Sedimentary Geology, 155: 317-342

Anokhin, Yu. A. 2002: Impacts of environmental factors on Lake Baikal ecosystem. Proceedings of All-Russia Conference "Ecological Problems in Russia" Moscow, Nauka (in Russian with an English Abstract), 241-252.

Anon., 2000: Agriculture in Russia, Statistical Report, Goscomstat, Moscow, 130 pp. (in Russian).

Asche, F. and S.Tveteras, 2004: On the relationship between aquaculture and reduction fisheries. Journal of Agricultural Economics, 55 (2), 245-265.

Ashrit, R., H. Douville and K. Rupa Kumar, 2003: Response of the Indian monsoon and ENSO-monsoon teleconnection to enhanced greenhouse effect in the CNRM coupled model, J. Meteor. Soc. Japan, 81, 779-803.

Baker, A.C., C.J. Starger, T.R. McClanahan, and P.W. Glynn, 2004: Corals' adaptive response to climate change, Nature, 430, 741.

Bangs, M., and D. B. Subianto, 1999: El Niño and associated outbreaks of severe malaria in highland populations in Irian Jaya, Indonesia: a review and epidemiological perspective: Southeast Asian Journal of Tropical Medicine and Public Health, 30(4), 608-619.

Batima P., Batnasan N., and Lehner B., 2004b: The Freshwater Systems of Western Mongolia's Great Lakes Basin: Opportunities and Challenges in the Face of Climate Change, ADMON publishing Ulaanbaatar, 95pp.

Batima, P., 2003: Climate change: Pasture-Livestock, Synthesis report – Potential Impacts of Climate Change, Vulnerability and Adaptation Assessment for Grassland Ecosystem and Livestock Sector in Mongolia, ADMON publishing Ulaanbaatar, pp.36-47.

Batima, P., L. Natsagdorj, B. Bolortsegtseg, G. Tuvaansuren, B. Bayarbaatar, B. Erdenetsegtseg and N. Natsagsuren, 2004a: Past and present changes in the climate, rangelands, and livestock of Mongolia, AIACC Notes, 2 (1), pp.7-9.

Batima, P., Natsagdorj, L., Gomboluudev, P., and B.Erdenetsetseg, 2005: Observed climate change in Mongolia. AIACC Working paper No 13.

Baysgalan, Sh., L. Natsagdorl, and G. Tuvaansuren, 2000: Impact on agriculture in "Climate Change and Its Impacts in Mongolia", Batima P. and Dagvadorj D. (eds) NAMHEM and JEMR publishing, Ulaanbaatar, pp.47-97.

BBC (British Broadcasting Coorporation) News, 2002: Heat abates in southern India, 17 May (http://news.bbc.co.uk/1/hi/world/south_asia/1992806.stm).

Bhadra, B., 2002: Regional cooperation for sustainable development of Hindu Kush Himalaya region: Opportunities and challenges, Keynote paper presented at the Alpine Experience – An Approach for other Mountain Regions, Berchtesgaden, Germany, June 26-29.

Blaikie, P.M.; Cannon, R.; Davies, I. and Wisner, B., 1994: At Risk: Natural Hazards, People's Vulnerability, and Disasters. Routledge, New York.

Boer, R. and A. Faqih, 2004: Current and future rainfall variability in Indonesia, AIACC Technical Report 021.

Bolortsetseg, B. and B. Gantsetseg, 2002: Annual report on Past Climate change in Mongolia, Potential Impacts of Climate Change, Vulnerability and Adaptation Assessment for Grassland Ecosystem and Livestock Sector in Mongolia, AIACC Project Report.

Boo, K. O., W. T. Kwon and J. K. Kim, 2005: Vegetation changes in regional surface climate over east Asia due to Global Warming using BIOME 4II, Nuovo Cimento (submitted).

Bouma, M. J., and H. J. van der Kaay, 1996: The El Niño Southern Oscillation and the historic malaria epidemics on the Indian subcontinent and Sri Lanka: An early warning system: Tropical Medicine and International Health, 1(1), 86-96.

Bouma, M. J., and M. Pascual, 2001: Seasonal and interannual cycles of endemic cholera in Bengal 1891-1940 in relation to climate and geography: Hydrobiologia, 460, 147-156.

Burke, L., E. Selig, and M. Spalding, 2002: Reefs at Risk in Southeast Asia Data CD. Washington, DC, World Resources Institute.

Cai, Y., Li, D.L, Tang, M.C.and C. Y. Bai, 2003: Decadal temperature change over Qinghai-Xizang Plateau in recent 50 years. Plateau Meteorology, 22(5), 464-470.

Chandrapala, L. and T.K. Fernando, 1995: Climate variability in Sri Lanka - a study of air temperature, rainfall and thunder activity. In: Proceedings of the International Symposium on Climate and Life in the Asia-Pacific, University of Brunei, Darussalam, 10–13 April, 1995.

Chandrapala, L., 1996: Long term trends of rainfall and temperature in Sri Lanka, In Climate Variability and Agriculture [Eds: Abrol, Y.P., S. Gadgil and G.B. Pant], Narosa Publishing House, New Delhi, pp.153-162.

Checkley, W., L.D. Epstein, R.H. Gilman, D. Figueroa, R. Cama, J.A. Patz, and R.E. Black, 2000: Effects of El Niño and ambient temperature on hospital admissions for diarrhoel diseases in Peruvian children: Lancet, 355.

Chen, J., An, Z. S. and Liu, L. W., 2001: Variations in Chemical Compositions of the Eolian Dust in Chinese Loess Plateau over the past 2.5 Ma and Chemical Weathering in the Asian Inland, Science in China (Series D), 44(5), 403-413.

Chen, X.Q., 1991: Sea-Level Changes since the Early 1920s from the Long Records of Two Tidal Gauges in Shanghai, China, Journal of Coastal Research, 7 (3), 787-799.

Chiffings, T., 2004: Marine region 11: Arabian Seas, (www.deh.gov.au/coasts/mpa/nrsmpa/global/volume3/chapter11.htm).

Choi, B.H., D. H. Kim and J.W. Kim, 2002: Regional responses of climate in the Northwestern Pacific Ocean to gradual global warming for a CO_2 quadrupling, J. Meteor. Soc. Japan, 80, 1427-1442.

Choi, Y., R. V. Rohli, S.K. Min, S. Lee and W.T. Kwon, 2004: Trends on climate extremes in South Korea during the second half of the twentieth century, Int. J. Climatol. (submitted).

Christensen, L., M. B. Coughenour, J.E. Ellis, and Z.Z. Chen, 2004: Vulnerability of the Asian typical steppe to grazing and Climate Change. Climate Change, 63(3), 351-368.

Church, J.A., J.M. Gregory, P. Huybrechts, M. Kuhn, K. Lambeck, M.T. Nhuan, D. Qin, and P.L. Woodworth, 2001: Changes in Sea Level. In Climate Change 2001: The Scientific Basis.

Contribution of Working Group 1 to the Third Assessment Report of the Intergovernmental Panel on Climate Change [Houghton, J.T., Y. Ding, D.J. Griggs, M. Noguer, P. van der Linden, X. Dai, K. Maskell and C.I. Johnson (eds)] Cambridge University Press, 639-694.

Clark, J. R., 1996: Coastal Zone Management Handbook, CRC Lewis Publishers, Boca Raton, 669pp.

Climate Change and Public Health in Russia in the 21st century, 2004: Proceedings of the Intl. Conf. held during April 5-6, 2004, [Editors: Prof. N.F. Izmerov, Prof. B.A. Revich, Prof. E.I. Korenberg] Russian Academy of Medical Sciences - Russian Regional Committee for Cooperation with UNEP Center for Demography and Human Ecology Russian Regional Environmental Center Non-Governmental Organization “Environmental Defense”, Moscow, 461 pp.

Climate Change in Russia, 2003: IGCE Russian Agency on Hydrometeorology and Environmental Monitoring Publishing Moscow, 210 pp. (in Russian with an English abstract).

Climate Change, 2004: Scientific analysis of the results of World Climate Change Conference, Moscow, 222 pp. (in Russian with an English abstract).

Coleman, L., 2004: Shatt Al-Arab River Delta, Iraq, Asia (www.geol.lsu.edu/WDD/ASIAN/ Shatt-al-Arab/shatt-al-arab.htm - 14k).

Collins, M., 1999: The El-Nino Southern Oscillation in the second Hadley Centre coupled model and its response to greenhouse warming, J. Climate, 13, 1299-1312.

Colwell, R. R., 1996: Global climate and infectious disease: the cholera paradigm: Science, 274, 2025-2031.

Cruz, R.V.O., R.D. Lasco, J.M. Pulhin, F. B. Phulin and K. B. Garcia, 2005: Climate change impact on water resources in Pantabangan Watershed, Philippines, AIACC Technical Report.

CWC (Central Water Commission), 2001: Water and related statistics, Report of the Ministry of Water Resources, New Delhi.

De, U.S. and R.K. Mukhopadhyay, 1998: Severe heat wave over the Indian subcontinent in 1998 in perspective of global climate, Current Science, 75(12), 1308-1315.

Ding, L., Li B.Y., Zhang S.S., 2004: Advances in researches on seawater intrusion of coastal area, Marine Science Bulletin, 23 (2), 82-87 (in Chinese with an English abstract).

Ding, Z.Q. and Pan H.S., 2002: The causes and prediction of flood disaster in Heilongjiang Provinces. Heilongjiang Science and Technology of Water Conservancy, 3, 5-7.

Droogers, P., 2004: Adaptation to climate change to enhance food security and preserve environmental quality: Example for southern Sri Lanka. Agricultural-Water-Management. 2004 APR 01; 66(1): 15-33

Du, B.L. and J.W. Zhang, 2000: Adaptation strategy for sea-level rise in vulnerable areas along China’s coast. Acta Oceanologica Sinica, 19, 1-16.

Du, B.L., 1997: The impacts of sea-level rise on the major vulnerable areas of the China’s coastal zone and related strategies, Beijing, China Ocean Press, 166p (in Chinese with English abstract).

Du, J. and Y. C. Ma, 2004: Climatic trend of rainfall over Tibetan Plateau from 1971 to 2000. ACTA GEOGRAPHICA SINICA, 59(3), 375-382.

Duedall, I.W. and Maul G.A., 2005: Demography of coastal populations. In M. L. Schwartz (ed.), Encyclopedia of coastal science, Springer, Dordrecht, The Netherlands, 368-374.

Duong, Lien Chau, 2000: Lessons from severe tropical storm Linda, Workshop report: "The Impact of El Niño and La Niña on Southeast Asia", 21-23 February, Hanoi.

Durkin, M.S., N. Khan, L.L. Davidson, S.S. Zaman and Z.A. Stein, 1993: The effects of a natural disaster on child behaviour: Evidence for post-traumatic stress, American Journal of Public Health, 83(11), 1522-1524.

Emori, S., T. Nozawa, A. Numaguchi and I. Uno, 2000: A regional climate change projection over East Asia, Preprint Volume of the 11th Symposium on Global Change Studies, 9-14 January 2000, Long Beach, California, 15-18.

Environment News Service, 2002: Hungry Cambodians at the Mercy of Climate Change,

PhnomPenh, 26 November, posted at fttp://ens_news.xom/ens/nov2002/2002-11-26-02.asp (accessed 15/01/03).
Erdenetsetseg, B., 2005: Climate change impacts on snow cover, In Climate change – Pasture and livestock (Eds: Batima P., Bat, B. and Tserendorj), Ulaanbaatar. ADMON: 13-25.
Erdnethuya, M., 2003: Annual report on Forest and steppe fires in Mongolia - Potential Impacts of Climate Change, Vulnerability and Adaptation Assessment for Grassland Ecosystem and Livestock Sector in Mongolia project, AIACC Project Report.
Fan, D.D. and Li C. X., 2005: Complexities of Chinese Coast in Response to Climate Change. Advance in Research on Climate Change, (in Chinese with an English abstract) (in press).
FAO (Food and Agriculture Organization) / WFP (World Food Programme), 2000: 'FAO/WFP Crop and Food Supply Assessment Mission to Cambodia', Special Report, 29 December 2000, FAO Global Information and Early Warning System on Food and Agriculture/World Food Programme.
FAO (Food and Agriculture Organization), 2000: The State of Food and Agriculture 2000, Rome: FAO.
FAO (Food and Agriculture Organization), 2002: Food Insecurity, poverty and agriculture: A concept paper ESA02/15 by Sumiter S. Broca, Agriculture and Development Economics Division of the Foof and Agriculture Organization, Rome.
FAO (Food and Agriculture Organization), 2003: "World agriculture: towards 2015/2030 – An FAO Perspective", Bruinsma (ed.), FAO, Rome and Earthscan, London.
FAO (Food and Agriculture Organization), 2004a: Yearbook of Fishery Statistics 2002. Capture production, Vol. 94/1, Food and Agriculture Organization of the United Nations, Rome, Italy, 654 pp.
FAO (Food and Agriculture Organization), 2004b: Yearbook of Fishery Statistics 2002, Aquaculture production, Vol. 94/2, Food and Agriculture Organization of the United Nations, Rome, Italy, 206 pp.
FAO (Food and Agriculture Organization), 2004c: Data Base, Food and Agriculture Organization of the United Nations, Rome, Italy.
FAO (Food and Agriculture Organization), 2005: Background document on Special event on impacts of climate change, pests and diseases on food security and poverty reduction, 31st Session of the Committee on World Food security, 23-25 May.
Farooq, A. B. and A. H. Khan, 2004: Climate change perspective in Pakistan, Proc. Capacity Building APN Workshop on global change research, Islamabad, Pakistan, June 8-10, 2004, 39-46.
Federov, A. and P. Konstantinov, 2003: Observations of surface dynamics with thermokarst initiation, Yukechi site, Central Yakutia. In: Proceedings of the *VII International Permafrost Conference*, Switzerland, July 21-25, pp. 239-243.
Fischer, G., Mahendra Shah and Harrij van Velthuizen, 2002: Climate Change and Agricultural Variability, A special report, on "Climate Change and Agricultural Vulnerability", Contribution to the World Summit on Sustainable Development, Johannesburg 2002.
Fitzharris, 1996: The cryosphere: Changes and their impacts. In Climate Change 1995: The Science of Climate Change, (Eds J. T. Houghton, L. G. M. Filho, B. A. Callander, N. Harris, A. Kattenberg, and K. Maskell), 241-265, Cambridge University Press, Cambridge, UK.
Frolov, I., Alekseev G., Danilov, A., 2004: Climate change in polar areas, in Proceedings of World Climate Change Conference, Moscow, 29 September – 3 October 2003, 484-490 pp.
Fukushima, T., M. Kureha, N. Ozaki, Y. Fujimori, and H. Harasawa, 2002: Influences of air temperature change on leisure industries: case study on ski activities. Mitigation and Adaptation Strategies for Global Change, 7, 173-189.
Ganbaatar, T. and Tumerbaatar, D., 2005: Climate change impacts on permafrost, In Climate change – Pasture and livestock, (Eds: Batima, P., Bat, B. and Tserendorj), Ulaanbaatar. ADMON: 26-33.

Gao, X. J., Z. C. Zhao and F. Giorgi, 2002: Changes in extreme events in regional climate simulations over east Asia, Advances in Atmospheric Sciences, 19, 927-942.

Gao, X. J., Z. C. Zhao, Y. H. Ding, R. H. Huang and F. Giorgi, 2001: Climate change due to greenhouse effects in China as simulated by a regional climate model, Advances in Atmospheric Sciences, 18, 1224-1230.

Gao, X.J., D.L. Li, Z. C. Zhao and F. Giorgi, 2003: Climate change due to greenhouse effects in Qinghai-Xizang Plateau and along Qianghai-Tibet Railway, Plateau Meteorology, 22(5), 458-463 (In Chienese with English abstract).

Gavriliev, P. P. and P. V. Efremov, 2003: Effects of cryogenic processes on Yakutian landscapes under climate warming. In: Proceedings of the VII International Permafrost Conference, Switzerland, July 21-25, pp. 277-282.

Ge, D.K., Jin, Z.O., Shi, C.L. and Gao, L.Z., 2002: Gradual impacts of climate change on rice production and adaptation strategies in southern China, Jiangsu Journal of Agricultural Science, 18 (1), 1-8.

Glantz, M.H. (Ed.) 2001: Once Burned, Twice Shy? Lessons Learned from the 1997-98 El Niño, United Nations University, 294 pp.

Golitsyn, G. S. and Izrael Yu. A. (Eds), 2002: Global Climate Change and its impacts on Russia, Moscow, Ministry of Industry and Science, 465 pp. (in Russian).

Golubev, G. and N. Dronin, 2003: Geography of droughts and food problems in Russia of the Twentieth Century, Research Monograph of the Center for Environmental Systems Research, University of Kassel and Department of Geography, Moscow State University, 25 pp.

Gomboluudev, P., 2002: Annual report on observed climate change, Potential Impacts of Climate Change, Vulnerability and Adaptation Assessment for Grassland Ecosystem and Livestock Sector in Mongolia, AIACC Project Report.

Gopal, Brij, 2004: Future of wetlands in Asia (www.ramsar.org/archives/archives_bulletin 031202.htm).

Groombridge, B. and M. D. Jenkins, 2002: *World Atlas of Biodiversity*, Univ. of California Press, Berkeley, USA.

Gruza, G. and Rankova E. 2004: Detection of changes in climate state, climate variability and climate extremity, in Proc. World Climate Change Conference, 29 September – 3 October, 2003, Moscow, pp.90-93.

Gruza, G. V., E. Ya. Rankova, V. Razuvaev and O. Bulygina, 1999: Indicators of climate change for the Russian Federation. Climatic Change, Kluwer Academic Publishers, Dordrecht, Boston, London.

Guo, Q.X., Li J.L., Liu J.X. and Zhang Y.M., 2001: The Scientific Significance of the Forest Vegetation Ecotone between Daxing'an and Xiaoxing'an Mountains to Global Climate Change Study, Journal of Forestry, Northeast University, 29(5), 1-4.

Han, M., Zhao M. H., Li D.G. and Cao X.Y., 1999: Relationship between ancient channel and seawater intrusion in the south coastal plain of the Laizhou Bay. Journal of Natural Disasters, 8(2): 73-80.

Hara, Y., K. Takeuchi and S. Okubo, 2004: Urbanization linked with past agricultural landuse patterns in the urban fringe of a deltaic Asian mega-city: a case study in Bangkok, Landuse and Urban Planning, (in press).

Harasawa, H. and S. Nishioka, (eds.) 2003: Climate Change on Japan, KokonShoin Pub (In Japanese).

Hasnain, S. I., 2002: Himalayan Galciers meltdown: Impacts on South Asian Rivers, IAHS Pub. No.274, pp.1-7.

Hasumi, H. and S. Emori (eds.), 2004: K-1 coupled model (MIROC) description, K-1 technical report, 1, Center for Climate System Research, University of Tokyo, 34pp.

Hewitt, K., 1997: Regions of Risk: A Geographical Introduction to Disaster. Longman, England. 389pp.

Hinzman, L.D., Kane, D.L., Yoshikawa, K., Carr, A., Bolton, W.R., and M. Fraver, 2003: Hydrological variations among watersheds with varying degrees of permafrost. In: Proceedings of the VII International Permafrost Conference, Switzerland, July 21-25, pp. 407-411.

Ho, C.H., J.Y. Lee, M.H. Ahn and H.S. Lee, 2003: A Sudden Change in Summer Rainfall Characteristics in Korea during the Late 1970s, Int. J. Climatol., 23, 117-128.

Honda, Y., M. Ono M, I. Uchiyama and A. Sasaki A., 1998: Shift of the short-term temperature-mortality relationship by a climate factor - some evidence necessary to take account in estimating the health effect of the global warming. J. Risk Res., 1, 209-220.

Hu, D.X., W.Y. Han and S. Zhang, 2001: Land-Ocean interaction in Changjiang and Zhujiang Estuaries and adjacent sea areas, Beijing, China Ocean Press, 218 pp. (in Chinese).

Hu, Z. Z., S. Yang and R. Wu, 2003: Long-term climate variations in China and global warming signals. Jr Geophys Research, 108.

Huang, H. J., Li F., Pang J.Z., Le K.T., Li S.G., 2005: Land-Ocean Interaction between Huanghe Delta and Bohai Gulf and Yellow Sea, China Science Press, Beijing, 313 pp., (in Chinese).

Huang, Z.G. and Xie X.D., 2000: Sea level changes in Guangdong and its impacts and strategies. Guangzhou: Guangdong Science and Technology Press, 263 pp.

Huijin, Y. U. *et al*., 2000: The thermal state of permafrost, An IPA contribution to the International polar year, IDEA No. 058 (in How rapidly is permafrost changing and what are the impacts of these changes? (www.arctic.noaa.gov/essay_romanovsky.html).

Hulbe, C. L. and A. J. Payne, 2001: Numerical modelling of the West Antarctic Ice Sheet, Antarctic Research Series, 77, 201-220.

Hulme, M. and Nicola Sheard, 1999a: Climate change scenarios for Indonesia, Climate Research Unit, Norwich, UK, 6pp.

Hulme, M. and Nicola Sheard, 1999b: Climate change scenarios for the Philippines, Climate Research Unit, Norwich, UK, 6pp.

Huynen, M., P. Martens, D. Schram, M.P. Weijenberg and A.E. Kunst, 2001: The Impact of Heat Waves and Cold Spells on Mortality Rates in the Dutch Population, Environ. Health Perspect, 109, 463-470.

Iafiazova, R.K., 1997: Climate change impact on mud flow formation in Trans-Ili Alatay mountains. Hydrometeorology and Ecology, 3, 12-23. (in Russian).

Ichikawa, A. (ed.), 2004: Global Warming – The Research Challenges, A Report of Japan's Global Warming Initiative, Springer, 160pp.

IFRCRCS (International Federation of Red Cross and Red Crescent Societies), 2004: World Disaster Report Focus on community resilience, 231pp.

Inam, A., Khan T. M. Ali, Tabrez A. R., Amjad S., Danish M., Tabrez S. M., 2003: Natural and man made stresses on the stability of Indus Deltaic eco-region (www.waterandnature.org/econ/CaseStudy05Indus.pdf).

Intergovernmental Panel for Climate Change, 2001: Climate Change 2001 – Impacts, Adaptation and Vulnerability, Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change [Eds: J.J. McCarthy, O.F. Canziani, N. A. Leary, D.J. Dokken and K.S.White], Cambridge University Press, USA & UK, 1032 pp.

Isaev, A., Stolbovoi, V., Kotlyakov, V., Nilsson S. and McCallum I., 2004: Climate change and land resources of Russia, In Proc. World Climate Change Conference, 29 September – 3 October 2003, Moscow, 234-240.

Isobe, H., 2002: Trends in precipitation over Japan, Proceedings of the 6^{th} Symposium on water resources, 585-590.

IUCN (The World Conservation Union - Pakistan Country Office, Karachi), 2003: Indus Delta, Pakistan: Economic costs of reduction in freshwater flows, (www.waterandnature.org/econ/CaseStudy05Indus.pdf).

Izrael, Yu. A. (Ed.) 2002: Scientific aspects of environmental problems in Russia, All-Russia Conference Proceedings, Moscow, Nauka, vol 1 622 pp. and vol 2 (650 pp.) (in Russian).

Izrael, Yu. A. and Anokhin Yu. A. 2000: Monitoring and assessment of the environment in the Lake Baikal region, Aquatic Ecosystem Health & Management, vol. 3, p.199-202.
Izrael, Yu. A. and Anokhin Yu. A., 2001: Climate change impacts on Russia. In: Integrated environmental monitoring, Moscow, Nauka (in Russian with an English abstract), 112-127.
Izrael, Yu. A., Anokhin Yu. A. and Pavlov A. V., 2002: Permafrost evolution and the modern climate change. Meteorology and Hydrology, No.1, 22-34.
Jafari, M., 2003: Ecological classification of forests in Iran and IPF/IFF proposal for action, Report of the Food and Agriculture Organization Representative on Iran, 71pp.
Japan Meteorological Agency, 2002: Climate of Japan in 20th century, 116pp. (in Japanese).
Japan Meteorological Agency, 2005: Global Warming Projection, Vol.6 - with the RCM20 and with the UCM, 58pp. (In Japanese).
Jennings, S., D. P. Boullé, and N.V.C. Polunin, 1996: Habitat correlates of the distribution and biomass of Seychelles reef fishes, Environ. Biol. Fish., 46: 15–25.
Jiang, Z. H., Wu L. Y., Ou W. Y., 2002: 2001-2002 report on Chinese metropolitan development, www.chinacsw.com/xinwen/dyt4.htm.
Jin, Z.O., Shi, C.L., Ge, D.K. and Gao, W., 2001: Characteristic of climate change during wheat growing season and the orientation to develop wheat in the lower valley of the Yangtze River, Jiangsu Journal of Agricultural science, 17(4), 193-199.
Jorgenson, M.T., Racine, C.H., Walters, J.C., and Osterkamp, T.E., 2001: Permafrost degradation and ecological changes associated with a warming climate in central Alaska. Climatic Change, 48(4), 551-571.
Jung, H.-S., Y. Choi, J.-H. Oh, and G.-H. Lim, 2002: Recent trends in temperature and precipitation over South Korea. International Journal of Climatology, 22, 1327-1337.
Kainuma, M., Y. Matsuoka, T. Morita (Eds), 2003: Climate Policy Assessment Asia-Pacific Integrated Modeling, Springer, 402pp.
Kajiwara, M., T. Oki and J. Matsumoto, 2003: Inter-annual variability of the frequency of severe rainfall in the past 100 years over Japan, Extended abstract (in Japanese) for a bi-annual meeting of the Meteorological Society of Japan.
Kalra, N., Aggarwal P.K., Chander S., Pathak H., Choudhary R., Chaudhary A., Mukesh S., Rai H.K., Soni U.A., Anil S., Jolly M., Singh U.K., Owrs A., and Hussain M.Z., 2003: Impacts of Climate Change on Agriculture, in Climate Change and India:Vulnerability Assessment and Adaptation. Shukla P.R., Subodh K.S., Ravindranath N.H. Garg A. and Bhattacharya S. (eds) University Press, India. 191-226.
Kanai, S., T. Oki and A. Kashida, 2004: Changes in Hourly Precipitation at Tokyo from 1890 to 1999. J. Meteor. Soc. Japan, 82, 241-247.
Kato, H., K. Nishizawa, H. Hirakuchi, S. Kadokura, N. Oshima and F. Giorgi, 2000: Performance of RegCM2.5/NCAR-CSM nested system for the simulation of climate change in East Asia caused by global warming,J. Meteor. Soc. Japan, 79, 99-121.
Kawahara, M. and N. Yamazaki, 1999: Long-term trend of incidences of extreme high or low temperatures in Japan, Extended abstract (in Japanese) for a bi-annual meeting of the Meteorological Society of Japan.
Kelly, P.M. and Adger, W.N., 2000: Theory and Practice in Assessing Vulnerability to Climate Change and Facilitating Adaptation, *Climate Change*, 47, 325-352
Khomyakov, P. M. and V. I. Kuznetsov, 2001: Impact of global climate changes on the functioning of major sectors of the economy and health of population of Russia, Editorial, Moscow (in Russian).
Kirpichnikov, M., Reutov B., Novikov A. 2004: Scientific and technical projections of the Russian energy sector development as a factor of reduction of the negative climate change, in Proceedings of World Climate Change Conference, 29 September – 3 October 2003, Moscow, 413-417.
Knutson, T. R. and R. E. Tuleya, 2004: Impacts of CO2 induced warming on simulated hurricane intensities and precipitation: sensitivity to the choice of climate model and convective

parameterization, Jr. Climate, 17, 3477-3495.
Kovats, R.S., M.J. Bouma, S. Hajat, E. Worrall and A. Haines, 2003: El Niño and health. Lancet 362, 1481-89.
Kripalani, R.H., A. Kulkarni, S.S. Sabade and M.L. Khandekar, 2003: Indian Monsoon variability in a global warming scenario. Natural Hazards, 29(2), 189-206.
Kripalani, R.H., S.R. Inamdar, and N.A. Sontakke, 1996: Rainfall variability over Bangladesh and Nepal: comparison and connection with features over India. International Journal of Climatology, 16, 689–703.
Kudo, G., Y. Nishikawa, Kasagi, and S. Kosuge, 2004: Does seed production of spring ephemerals decrease when spring comes early? Ecological Research, 19, 255-259.
Kurihara, K., K. Ishihara, H. Sakai, Y. Fukuyama, H. Satou, I. Takayabu, K. Murazaki, Y. Sato, S. Yukimoto and A. Noda, 2005: Projections of climatic change over Japan due to global warming by high resolution regional climate model in MRI, SOLA (In press).
Kwon, W. T., I. C. Shin, H. J. Baek, Y. Choi, K. O. Boo, E. S. Im, J. H. Oh and S. H. Lee, 2004: The development of regional climate change scenario for the National climate change Report (III), (Korean), METRI Technical Report (In Press).
Lal, M, 2001: Tropical Cyclones in a Warmer World, Current Science, Vol 80(9), 1103-1104.
Lal, M., 2002: Global Climate Change - India's monsoon and its variability, Final Report under "Country Studies Vulnerability and Adaptation" Work Assignment with Stratus Consulting's Contract of the U.S. Environmental Protection Agency, September 2002, 58pp.
Lal, M., 2003: Global Climate Change: India's monsoon and its variability, Journal of Environmental Studies and Policy, 6 (1), 1-34
Lal, M., 2005: Implications of climate change on agricultural productivity and food security in South Asia, In "Key vulnerable regions and climate change" - Identifying thresholds for impacts and adaptation in relation to Article 2 of the UNFCCC", European Climate Forum (In press).
Lal, M., G. Srinivasan, and U. Cubasch, 1996: Implications of global warming on the diurnal temperature cycle of the Indian subcontinent, Curr. Sci., 1996, 71(10), 746-752.
Lal, M., K. K. Singh, L. S. Rathore, G. Srinivasan, S. A. Saseendran, 1998: Vulnerability of Rice and Wheat Yields in NW - India to Future Changes in Climate, Agri. & Forest Meteorol., 89, 101-114.
Lal, M., T. Nozawa, S. Emori, H. Harasawa, K. Takahashi, M. Kimoto, A. Abe-Ouchi, T. Nakajima, T. Takemura and A. Numaguti, 2001: Future Climate Change: Implications for Indian Summer Monsoon and its Variability, Current Science, 81(9), 1196-1207.
Leont'yev, I.O., 2004: Coastal profile modeling along the Russian Arctic coast, Coastal Engineering, 51: 779–794.
Li, B. and Zhou, C., 2001: Climatic Variation and Desertification in West Sandy Land of Northeast China Plain. Journal of Natural Resources, 16(3), 234-239.
Li, C.X, D.D. Fan, B. Deng and V. Korotaev, 2004a: The Coasts of China and Issues of Sea Level Rise. Journal of Coastal Research, 43, 36-47.
Li, C.X., S.Y. Yang, D.D. Fan, and J. Zhao, 2004b: The change in Changjiang suspended load and its impact on the delta after completion of Three-Gorges Dam. Quaternary Sciences, 24 (5): 495-500 (in Chinese with an English abstract).
Li, C.X., Wang, P., Fan, D.D., and Deng, B., 2000: Bruun rule and its application to the coastal zone of China, Marine Geology and Quaternary Geology, 20 (1), 87-91 (in Chinese with an English abstract).
Li, C.Y., and Xian P., 2003: Inter-decadal Variation of SST in the North Pacific and the Anomalies of Atmospheric Circulation and Climate, Climatic and Environmental Research, 8 (3): 258-273.
Li, Q.F., Li, F.S., and Wu, L., 2002: A primary analysis on climatic change and grassland degradation in Inner Mongolia. Agricultural Research in the Arid Areas, 20 (4), 98-102.

Li, Y.C. *et al*., 2000: Impacts of Climate Change on Sustainable Water Resources Use and Its Countermeasures in Ningxia Hui Autonomous Region, see: Climate Change and Prospect for Arid Areas in Western China, Beijing: Weather Press, 341-342.

Lin, E.D., Xu, Y.L., Ju, H. and Xiong, W., 2004: Possible adaptation decisions from investigating the impacts of future climate change on food and water supply in China, Proc. AIACC Asia-Pacific region workshop, Manila, Philippines, 5-8 November 2004.

Liu, C. M. and Chen, Z. K., 2001: Assessment on Water Resources Status and Analysis on Supply and Demand Growth in China, China Water Conservancy and Hydropower Press, Beijing.

Liu, C. Z., 2002: Suggestion on Water Resources in China Corresponding with Global Climate Change, China Water Resources, No.2, 36-37.

Liu, S.G., Li, C.X., Ding, J., Li, X.Z., and Ivanov, V.V., 2001: The rough balance of progradation and erosion of the Yellow River delta and its geological meaning. Marine Geology & Quaternary Geology, 21 (4), 13-17.

Liu, S.R., Guo, Q.S. and Wang, B., 1998: Prediction of net primary productivity of forests in China in response to climate change. Acta Ecologica Sinica, 18(5), 478-483

Liu, X. D. and Chen, B. D., 2000: Climatic warming in the Tibetan Plateau during recent decades. Int. J. Climatol. 20: 1729–1742.

Lobitz, B., L. Beck, A. Huq, B. L. Wood, G. Fuchs, A. S. G. Faruque, and R. Colwell, 2000: Climate and infectious disease: use of remote sensing for detection of Vibrio cholerae by indirect measurement: Proc. Natl. Acad. Sci., 97(4), 1438-1443.

Loukos, H, P. Monfray, L. Bopp, and P. Lehodey, 2003: Potential changes in skipjack tuna (Katsuwonus pelamis) habitat from a global warming scenario: modelling approach and preliminary results. Fisheries Oceanography, 12 (4-5), 474-482.

Lu, J. J., 2003: Estuarine Ecology, Beijing, China Ocean Press, 318 pp (in Chinese).

Lu, X .R. and Lu, X. Y., 2003: Climate tendency analysis of warming and drying in grassland of Northeast Qingzang Plateau of China. Grassland of China, 24(4), 8-13

Manton, M.J., P.M. Della-marta, M.R. Haylock, K.J. Hennessy, N. Nicholls, L.E. Chambers, D.A. Collins, Gdaw, A. Finet, D. Gunawan, K. Inape, H. Isobe, T.S. Kestin, P. Lefale, C.H. Leyu, T. Lwin, L.Maitrepierre, N. Ouprasitwong, C.M. Page, J. Pahalad, N. Plummer, M.J. Salinger, R. Suppiah, V.L. Tran, B. Trewin, I. Tibig, and D. Lee, 2001: Trends in Extreme daily rainfall and temperature in Southeast Asia and the South Pacific; 1961–1998, Int. J. Climatol., 21, 269–284.

Marchenko, S.S., 2002: Results of monitoring of the active layer in the northern Tien Shan mountains, Earth Cryosphere, v. VI, 3, 25-34, 2002 (in Russian).

Matsen, H. and F. Jakobsen, 2004: Cyclone induced storm surge and flood forecasting in the northern Bay of Bengal. Coastal Engineering, 51: 277-296.

Matsui, T., T. Yagihashi, T. Nakaya, H. Taoda, S. Yoshinaga, H. Daimaru, and N. Tanaka, 2004a: Probability distributions, Fagus crenata forests following vulnerability and predicted climate sensitivity in changes in Japan. Jounal of Vegetation Science, 15, 605-614.

Matsui, T., T. Yagihashi, T. Nakaya, N. Tanaka, and H. Taoda, 2004b: Climate controls on distribution of Fagus crenata forests in Japan. Jounal of Vegetation Science, 15, 57-66.

Matuscenko, A.A., *et al*., 2004: Negative Trends in Epidemic Situation in Natural Habitats of Tick-borne Encephalitis in the South of Western Siberia, In Proceedings of the Intl Conf on Climate Change and Public Health in Russia, April 5-6, 2004, Moscow [Editors: Prof. N.F. Izmerov, Prof. B.A. Revich and Prof. E.I. Korenberg], pp.124-134.

McManus, J. W., 1996: Social and economic aspects of reef fisheries and their management, In: Polunin, N. V .C., & Roberts, C. M., (eds.) Coral Reef Fisheries, 249–281.

Meier, M., 1998: Land ice on Earth: A beginning of a global synthesis, Unpublished transcript of the 1998 Walter B. Langbein Memorial Lecture, American Geophysical Union Spring Meeting - 26 May 1998, Boston, MA.

Melnikov B. S. and Revson A. L., 2003: Remote sensing of northern regions of West Siberia,

Cryosphere of Earth, 4, 37-48 (in Russian).
Meshcherskaya, A. A. and B. G. Blazhevich, 1990: Catalogs of temperature and humidity characteristics with account of areas of spreading by economic regions of main productive zones of the USSR (1891-1983), Leningrad.
Mimura, N. and H. Yokoki, 2004: Sea level changes and vulnerability of the coastal region of East Asia in response to global warming, Chapter 17, SCOPE/START Monsoon Asia Rapid Assessment Report.
Min, S.K., W.T. Kwon, E.H. Park and Y. Choi, 2003: Spatial and temporal comparisons of droughts over Korea with East Asia. Int. J. Climatol., 23, 223-233.
Mirza, M.Q. and A. Dixit, 1997: Climate change and water management in the GBM Basins, Water Nepal, 5, 71–100.
Mirza, M.Q., 2002: Global warming and changes in the probability of occurrence of floods in Bangladesh and implications, Global Environmental Change, 12, 127–138.
Morita, T., J. Robinson, A. Adegbulugbe, J. Alcamo, E. Lebre La Rovere, N. Nakicenovic, H, Pitcher, P. Raskin, V. Sokolov, B. de Vries, D. Zhou, 2001: Greenhouse gas emission mitigation scenarios and implications. In: O. Davidson, B. Metz, R. Swart (Eds), Climate Change 2001: Mitigation. Cambridge University Press, Cambridge, UK, 115-166.
Munday, P. L., Jones, G. P., and M.J. Caley, 1997: Habitat specialisation and the distribution and abundance of coral-dwelling gobies, Mar. Ecol. Prog. Ser., 152: 227–239.
Murdiyarso, D., 2000: Adaptation to climatic variability and change: Asian perspectives on agriculture and food security, Environmental monitoring and assessment, 61(1), 123-131.
Natsagdorf, L., Tsetsral, B., and Natsagsuren, N., 2003: Large scale relationship between atmospheric drought in Mongolia and Ocean-atmoshpere, in "Ecology and sustainable development". Volume 7, 151-180.
Nelson, F. E., 2003: Geocryology: Enhanced: (Un)frozen in Time, *Science*, 299: 1673-1675.
Nicholls R. J. and Goodbred S. L., 2004: Towards integrated assessment of the Ganges-Brahmaputra Delta, (www.megadelta.ecnu.edu.cn/main/upload/RobertAPN_paper_Thailand
Nicholls, R.J., 1995: Coastal mega-cities and climate change. *GeoJournal*, 37, 369-379.
Nicholls, R.J., 2004: Coastal flooding and wetland loss in the 21st century: changes under the SRES climate and socio-economic scenarios, Global Environment Change, 14, 69-86.
Ninh, N.H., Luong Quang Huy and Mick Kelly, 2005: Social Vulnerability in Indochina, (paper submitted to MAIRS).
Nishioka, S. and H. Harasawa (eds.), 1998: Global Warming - The Potential Impact on Japan, Springer, 244pp.
Oberman, N.G. and G.G. Mazhitova, 2001: Permafrost dynamics in the north-east of European Russia at the end of the 20th century. Norwegian Journal of Geography, 55, 241-244.
Oda, K. and M. Ishii, 2001: Body color polymorphism in nymphs and ntaculatus (Orthoptera: Tettigoniidae) adults of a katydid, Conocephalus. Appl. Entomol Zool, 36(3), 345-348.
Oerke, E.C., H.W. Dehne, F. Schohnbeck and A.Weber, 1995: Crop Production and Crop Protection: Estimated Losses in Major Food and Cash Crops, Elsevier, Amsterdam and New York, 830 pp.
Öhman, M. C. and A. Rajasuriya, 1998: Relationships between habitat structure and fish assemblages on coral and sandstone reefs, Env. Biol. Fish., 53:19–31.
Öhman, M. C., Rajasuriya, A., and E. Olafsson, 1997: Reef fish assemblages in north-western Sri Lanka: distribution patterns and influences of fishing practices, Environ. Biol. Fish., 49: 46–61.
Öhman, M. C., Rajasuriya, A., and S. Svensson, 1998: The use of Butterflyfishes (Chaetodontidae) as bio-indicators of habitat structure and human disturbance, Ambio, 27: 708–716.
Ojima, D.S., X. Xiangming, T. Chuluun and X. S. Zhang, 1998: Asian grassland biogeochemistry: factors affecting past and future dynamics of Asian grasslands. In: Asian Change in the context of global climate change, [eds.: James N. Galloway and Jerry M. Melillo], IGBP

publication series vol. 3, pp. 128-144. Cambridge, Cambridge University Press.

Osterkamp, T.E., L. Vierek, Y. Shur, M.T. Jorgenson, C. Racine, A. Doyle and R.D. Boone, 2000: Observations of thermokarst and its impact on boreal forests in Alaska, U.S.A. Arctic, Antarctic and Alpine Research, 32, 303-315.

Paerl, H.W., J. Dyble, P.H. Moisander, R.T. Noble M.F. Piehler, J.L. Pinckney, T.F. Steppe, L. Twomey and L.M. Valdes, 2003: Microbial indicators of aquatic ecosystem change: current applications to eutrophication studies. FEMS Microbiology Ecology, 46, 233-246.

PAGASA (Philippine Atmospheric, Geophysical and Astronomical Services Administration), 2001: Documentation and analysis of Impacts of and responses to extreme climate events, Climatology & Agrometeorology Branch Technical Paper No. 2001-2, 30pp.

Pan, X.L., Deng, W. and Zhang, D.Y., 2003: Classification of Hydrological Landscapes of Typical Wetlands in Northeast China and Their Vulnerability to Climate Change, Research of Environmental Sciences, 16(1), 14-18.

Parikh, J. and K. Bhattacharya, 2004: South Asian Energy and Emission Perspectives for 21st Century, Report of the IIASA-World Energy Council Project on global energy perspectives for the 21st century, IIASA.

Parry, M., 2002: Scenarios for climate impacts and adaptation assessment, Global Environmental Change, 12, 149-153.

Parry, M., C. Rosenzweg, A. Iglesas, G. Fscher, and M. Lvermore.1999: Climate change and world food security: A new assessment, Global Environmental Change, 9, 51-67.

Parry, M.L., C. Rosenzweig, A. Iglesias, M. Livermore, and G. Fischer, 2004: Effects of climate change on global food production under SRES emissions and socio-economic scenarios, Global Environmental Change, 14, 53-67.

Pascual, M., M.J. Bouma, A.P. and Dobson A.P., 2002: Cholera and climate: revisiting the quantitative evidence. Microbes and Infection, 4, 237-245.

Pascual, M., X. Rodo, S.P. Ellner, R. Colwell, and M.J. Bouma, 2000: Cholera dynamics and El Niño Southern Oscillation: Science, 289, 1766-1767.

Pavlov, A.V., 1994: Current changes of climate and permafrost in the Arctic and Sub-Arctic of Russia, Permafrost and Periglacial Processes, 5, 101-110.

Pelling, M., 2003: The Vulnerability of Cities Natural Disasters and Social Resilience, Earthscan, 212pp.

Politov, S.V., Anokhin Yu. A., 2000: Estimation of the influence of the Chernobyl accident on the Baikal drainage basin, Aquatic Ecosystem Health & Management, vol. 3, p.227-229.

Pu, J.C., Yao, T. D., Wang, N.L., Su, Z., and Shen, Y.P., 2004: Fluctuations of the glaciers on the Qinghai-Tibetan Plateau during the past century. Journal of Glaciology and Geocryology, 26(5), 517-522.

Pulhin, J.M., Peras R.J.J., Cruz, R.V.O., Lasco, R.D., Pulhin, F.B., and Tapia, M.A. 2005: Vulnerability of Watershed Communities to Climate Variability and Extremes in the Philippines. AIACC-AS21 Working Paper No. 08.

Qian, Z.A., Wu, T.W., Song, M.H., Ma, X.B., Cai, Y. and Liang X.Y., 2001: Arid Disaster and Advances in Arid Climate Researches over Northwest China, Advance in Earth Sciences, 16(1):28-38.

Qian, Z.Y., 2001: Regional Water Resources Allocation, Environmental Construction and Strategies of Sustainable Development in Northwest China (http://www.cas.ac.cn/html/Dir/2003/03/07/8398.htm).

Qin, D. H., 2002: Assessment of Environment Change in Western China, 2nd Volume, Prediction of Environment Change in Western China, Beijing: Science Press , p64, 73, 115, 132, 145-154, 160-161.

Qiu, G.W., Hao, Y.X., and Wang, S.L., 2001: The Impacts of climate change on the interlock area of farming – pastoral region and its climatic potential productivity in Northern China. Arid Zone Research, 18(1), 23-28.

Rachmanin, Y. A. *et al*., 2004: Criteria for Assessment of Influence of Weather and Air Pollution on Public Health. In Proceedings of the Intl Conf. in Moscow, April 5-6, 2004 [Editors: Prof. N.F. Izmerov, Prof. B.A. Revich and Prof. E.I. Korenberg], pp. 171-175.
Rodo, X., M. Pascual, G. Fuchs, and A. S. G. Faruque, 2002: ENSO and cholera: a nonstationary link related to climate change?: Proc. Natl. Acad. Sci., 99(20), 12901-12906.
Romanovsky, V. E., Shender, N. I., Sazonova, T. S., Balobaev, V. T., Tipenko, G. S. and Rusakov, V. G., 2001: Permafrost Temperatures in Alaska and East Siberia: Past, Present and Future, in: Proceedings of the Second Russian Conference on Geocryology (Permafrost Science), Moscow, June 6-8, pp. 301-314.
Romanovsky, V., M. Burgess, S. Smith, K. Yoshikawa, and J. Brown, 2002: Permafrost Temperature Records: Indicators of Climate Change, EOS, AGU Transactions, Vol. 83, No. 50, 589-594.
Rosenzweig, C., A. Iglesias, X.B.Yang, Paul R.Epstein, and Eric Chivian, 2001: Climate change and extreme weather events: Implications for food production, plant diseases and pests, In Global change & human health, 2(2), Kluwer Academic Publishers, 90-104.
Royal Society, 2005: Food crops in a changing climate: Report of a Royal Society Discussion Meeting held in April 2005, Policy Document 10/05, (www.royalsoc.ac.uk).
Ruosteenoja, K., T.R. Carter, K. Jylha and H. Tuomenvirta, 2003: Future climate in world regions: An intercomparison of model based projections for the new IPCC emission scenarios, The Finnish Environment Report 644, Finnish Environment Institute, Helsinki, 83 pp.
Ryoo, S.B., W.T. Kwon and J.G. Jhun, 2004: Characteristics of wintertime daily and extreme temperature over South Korea, Int. J. Climatol., 24, 145-160.
Sakamoto, T., Yokozawa, M., Toritani, H., Shibayama, M., Ishitsuka, N., Ohno, H., 2005: A crop phenology detection method using time-series MODIS data, Remote Sensing of Environment, 96, 366-374.
Sato, Y., 2000: Climate Change prediction in Japan, Tenki, 47, 708-716 (in Japanese).
Savelieva, I.P., Semiletov, L.N. Vasilevskaya and S.P. Pugach, 2000: A climate shift in seasonal values of meteorological and hydrological parameters for Northeastern Asia, Progress Oceanography, 47, 279–297.
Seljaninov, G., 1966: Agroclimatic map of the world, Leningrad Publishing Center (in Russian).
Sharkhuu, N., 2003: Recent changes in the permafrost of Mongolia. In: Proceedings of the VII International Permafrost Conference, Switzerland, July 21-25, pp.1029-1034.
She, Z. X., 2004: Human-land interaction and socio-economic development, with special reference to the Changjiang Delta, Proceedings of Xiangshan Symposium on Human-land Coupling System of River Delta Regions: Past, Present and Future, October 19-21, Beijing (in Chinese).
Shen, X.T., Z.C. Mao and J.R. Zhu, 2003: Saltwater intrusion in the Changjiang Estuary. Beijing: China Ocean Press, 175 pp (in Chinese)
Shen, Y.P., Wang G.X., Wu Q. B. and Liu S.Y., 2002: The Impact of Future Climate Change on Ecology and Environments in the Changjiang - Yellow Rivers Source Region. Journal of Glaciology and Geocryology, 24(3), 308-313
Shi, Y. F., Shen Y.P., and Hu R.J., 2002: Preliminary Study on Signal, Impact and Foreground of Climatic Shift from Warm-Dry to Warm-Humid in Northwest China, Journal of Glaciology Geocryology, 24(3), 219-226.
Shimoda, Y., 2003: Adaptation measures for climate change and the urban heatisland in Japan’s built environment, Building Researches & Inforomation, 31(3/4), 222-230.
Shoigu, S. 2004: Global climate changes and emergencies in Russia, in Proc. of World Climate Change Conference. Moscow, 29 September – 3 October 2003, 73-85.
Short, F.T. and H.A. Neckles, 1999: The effects of global climate change on seagrasses. Aquatic Botany, 63, 169-196.
Shrestha, A. B., 2004: Climate Change in Nepal and its Impact on Himalayan Glaciers, Presented in

European Climate Forum Symposium on “Key vulnerable regions and climate change: Identifying thresholds for impacts and adaptation in relation to Article 2 of the UNFCCC”, Beijing, 27-30 October.

Siddiqui, K.M., Iqbal Mohammad and Mohammad Ayaz, 1999: Forest ecosystem climate change impact assessment and adaptation strategies for Pakistan, Climate Research, Vol. 12: 195–203

Simas, T., J.P. Nunes and J.G. Ferreira, 2001: Effects of global climate change on coastal salt marshes. Ecological Modelling, 139, 1–15.

Sin, S., 2000: Late Quaternary geology of the Lower Central Plain, Thailand. Journal of Asian Earth Sciences, 18, 415-426.

Singh, N. and N.A. Sontakke, 2002: On climatic fluctuations and environmental changes of the Indo-Gangetic plains, India, Climatic Change, 52, 287-313.

Singh, N., A.C. Nagpal, A. Saxena, and A.P. Singh, 2004: Changing scenario of malaria in central India, the replacement of Plasmodium vivax by Plasmodium falciparum (1986-2000), Tropical Medicine and International Health, 9, 364-371.

Sinha, S.K., G. B. Singh and M. Rai, 1998: Decline in Productivity in Punjab and Haryana: A Myth or Reality, ICAR Publication, New Delhi, 89pp.

Spalding, M., C. Ravilious, and E.P. Green, 2001: World Atlas of Coral Reefs. University of California Press, Berkeley, Los Angeles, Londen, 424pp.

Su, J.L. and Q.S. Tang, 2002: Study on Marine Ecosystem Dynamics in Coastal Ocean. II Processes of the Bohai Sea ecosystem Dynamics, Science Press, Beijing, China, 445pp.

Sukumar, R., K.G. Saxena and A. Untawale, 2003: Climate Change Impacts on Natural Ecosystem. in Climate Change and India: Vulnerability Assessment and Adaptation [Shukla P.R., Subodh K.S., Ravindranath N.H. Garg A., and Bhattacharya S. (eds.)], University press. India. p. 266-290.

Tao, F. and Yokozawa, M., 2005: Coping with Climate Risk in China: Developing a Food Security Warning System Using Seasonal Climate Forecasts. In the proceedings of ‘The International Workshop on Climate Prediction and Agriculture: Advances and Challenges’ WMO, Geneva, Switzerland, May 11-13th, 2005.

Tao, F., Yokozawa, M., Hayashi, Y. and Lin, E., 2003a: Changes in agricultural water demands and soil moisture in China over the last half-century and their effects on agricultural production, Agricultural and Forest Meteorology, 118: 251–261.

Tao, F., Yokozawa, M., Hayashi, Y. and Lin, E., 2003b: Future climate change, the agricultural water cycle, and agricultural production in China. Agriculture, Ecosystems and Environment, 95: 203–215.

Tao, F., Yokozawa, M., Hayashi, Y. and Lin, E., 2005: A perspective on water resources in China: interactions between climate change and soil degradation. Climatic Change, 68: 169-197.

Tao, F., Yokozawa, M., Zhang, Z., Hayashi, Y. Grassl, H. and Fu, C., 2004: Variability in climatology and agricultural production in China in association with the East Asia summer monsoon and El Niño South Oscillation, Climate Research, 28: 23-30.

TERI (Tata Energy Research Institute, New Delhi), 1996: The economic impact of one metre sea level risse on Indian coastline - Methods and case studies, Report submitted to the Ford Foundation.

Thanh, T.D., Saito Y., Huy D.V., Nguyen V.L., Ta T.K.O. and Tateish M., 2004: Regimes of human and climate impacts on coastal changes in Vietnam, Regional Environmental Change, 4: 49-62.

Timmermann, A., J. Oberhuber, A. Bacher, M. Esch, M. Latif and E. Roeckner, 1999: Increased El Niño frequency in a climate model forced by future greenhouse warming, Nature, 398, 694-696.

Tong, S. L. and L.V. Ying, 2000: Global Climate Change and Epidemic Disease, Journal of Disease Control, 4(1), 17-19.

Tran Viet Lien, 2002: Climate change scenario for Red River Catchments, University of Twente, The Northlands, 23pp.

Tran Viet Lien, Hoang Duc Cuong, Tran Thi Thao, 2005: Building of Climate Change Scenario for Red River Catchments for Sustainable Development and Environmental Protection, Science Workshop on Hydrometeorological Change in Vietnam and Sustainable Development, Hanoi, March 2005, 70-82pp.

Troadec, J.P., 2000: Adaptation opportunities to climate variability and change in the exploitation and utilisation of marine living resources; Environmental Monitoring and Assessment, v. 61, no. 1, p. 101–112.

Tuan D. T. and Molle F., 2003: The Chao Phraya delta in perspective: a comparison with the Red River and Mekong deltas, Vietnam, (std.cpc.ku.ac.th/delta/conf/Acrobat/Papers_Eng/Volume%202/DaoTheTuan.pdf).

Tumerbaatar, D., 2003: Annual report on Permafrost - Potential Impacts of Climate Change, Vulnerability and Adaptation Assessment for Grassland Ecosystem and Livestock Sector in Mongolia, AIACC Project Report.

Turner, J. R., Thrush, S. F., Hewitt, J. E., Cummings, V. J., and G. Funnell, 1999: Fishing impacts and the degradation or loss of habitat structure, Fisheries Management and Ecology, 6: 401–420.

Uchiyama, T., R. Mizuta, K. Kamiguchi, A. Kitoh and A. Noda, 2005: Changes in temperature-based extremes indices due to global warming projected by a global 20 km mesh atmospheric model, SOLA, Vol. 1; doi:10.2151/sola.

UNEP (United Nations Environment Programme), 2002: Global Environment Outlook-3, Earthscan, London, 410 p. + Annexes.

UN-HABITAT (United Nations Human Settlements Programme), 2004: The State of the World’s Cities 2004/2005 - Globalization and Urban Culture, Earthscan, 198pp.

Vaganov, E. and Shiyatov, S., 2004: Climate of the northern Eurasia in the late Holocene: information from the spatial network of the long-term tree-ring chronologies, in Proc. of World Climate Change Conference, 29 September – 3 October 2003, Moscow, 457-462.

Vasilevskaja, V. D., 2004: Degradation of tundra ecosystems, Cryosphere of Earth, 1, 53-63 (in Russian).

Vlek, P.L.G., K.G. Rodriguez and R. Sommer, 2004: Energy use and CO_2 production in tropical agriculture and means and strategies for reduction or mitigation. Environment Development and Sustainability, 6(1-2), 213-233.

Vorobyov, Yu., 2004: Climate Change and disasters in Russia, In Proceedings of the World climate change conference, Moscow, September 29-October 2003, pp.293-298.

Wada, N., K. Watanuki, K.Narita, S. Suzuki, G. Kudo and A. Kume, 2004: Climate Change and shoot elongation of Alpine Dwarf Pine(Pinus Pumila): Comparisons among Six Japanese Mountains, 6th APGC Symposium, 215.

Walsh, K. J. E., 2004: Tropical cyclones and climate change: Unresolved issues, Climate Research, 27, 77-84.

Wang J., Shen Y.P., Lu A.X., Wang L.H. and Shi Z.T., 2001: Impact of Climate Change on Snowmelt Runoff in the Mountainous Regions of Northwest China, Journal of Glaciology and Geocryology, 23 (1): 27-33.

Wang, F. T., 2002: Advances in climate warming impacts research in China in recent ten years, Journal of Applied Meteorological Science, 13 (6), 766.

Wang, M., Li, Y. and Pang, S., 2004a: Influences of climate change on sustainable development of the hinterland of Qinghai-Tibet Plateau, China Population, resources and Environment, 14(3), 92-95.

Wang, T., 2003: Study on desertification in China-2, Contents of desertification research. Journal Desert Research, 23(5), 477-482.

Wang, Y. B., Wang, G. X. and Chang, J., 2004b: Impacts of human activity on permafrost environment of the Tibetan Plateau. Journal of Glaciology and Geocryology, 26(5), 523-527.

Wassmann, R., Nguyen Xuan Hien, Chu Thai Hoanh and To Phuc Tuong, 2004: Sea Level Rise Affecting the Vietnamese Mekong Delta: Water Elevation in the Flood Season and Implications for Rice Production, Climatic Change, 66, (1-2), 89-107.
Webster, P. J., V.O. Magana, T.N. Palmer, J. Shukla, R.A. Tomas, M. Yanagi and T. Yasunari, 1998: Monsoons: Processes, predictability and the prospects for prediction, J. Geophys. Res., 103, 14451-14510.
Westmacott, S., Cesar, H., & Pet-Soede, L., 2000: Assesment of the Socio-economic impacts of the 1998 coral reef bleaching in the Indian Ocean: A summary, In: Souter, D., Obura, D., & Lindén, O., (eds.) CORDIO Status Report 2000.
WHO (World Health Organization), 2003: Climate Change and Human Health - Risks and Responses, in Methods of assessing human health vulnerability and public health adaptation to climate change, Health and Global Environmental Change No.1.
WHO (World Health Organization), 2004: Heat-waves: risks and responses, Health and Global Environmental Change, No.2.
Wijeratne, M. A., 1996: Vulnerability of Sri Lanka tea production to global climate change, Water, Air, & Soil Pollution (Historical Archive), 87 – 94.
Wilhelmsson, D., Öhman, M. C., Ståhl, H. and Y. Shlesinger, 1998: Artificial reefs and dive tourism in Eilat, Israel, Ambio, 27: 764–766.
Wilkinson, C., 2000: Status of Coral Reefs of the World: 2000: Australian Institute of Marine Science, Townsville, Australia, 363pp.
Wilkinson, C., 2002: Status of Coral Reefs of the World: 2002: Australian Institute of Marine Science, Townsville, Australia, 378pp.
Wilkinson, C., 2004: Status of Coral Reefs of the World: 2004, V.1, Australian Institute of Marine Science, Townsville, Australia, 302pp.
Wilkinson, P, D.H. Campbell-Lendrum and C.L. Bartlett, 2003: Chapter 10 - Monitoring the health effects of climate change, In [McMichael A.J., Campbell-Lendrum D.H., Corvalan C.F., Ebi K.L., Githeko A.K., Scheraga J.D., Woodward A. (eds.)] Climate change and human health - risks and responses, Geneva, World Health Organization, 204-219.
World Bank, 2002: World Bank Development Indicators, CD-ROM, Washington DC.
WRI (World resource Institute), 2003: World Resource 2002-2004. 315pp.
Wu Q.B., Li X. and Li W.J., 2001: The Response Model of Permafrost along the Qinghai – Tibetan Highway under Climate Change, Journal of Glaciology and Cryology, 23 1 :1-6.
Wu, S.Y., Yarnal, B., and Fisher, A., 2002: Vulnerability of coastal communities to sea-level rise: A case study of Cape May County, New Jersey, USA, *Climate Research*, 224, 255-270.
Wu, Z. F., 2003: Assessment of ecoclimatic suitability and climate change impacts on broad leaved Korean pine forest in Northeast China, Chinese Journal of Applied Ecology, 14(5), 771-775.
Xu, C.X., 2003: China national offshore and coastal wetlands conservation action plan. Beijing: China Ocean Press, 116 pp (in Chinese).
Yamano, H. and M. Tamura, 2004: Detection limits of coral reef bleaching by satellite remote sensing: simulation and data analysis. Remote Sensing of Environment, 90, 86-103.
Yang, G.S., 2000: Historic change and future trends of the storm surge disaster in China's coastal area. Journal of Natural disasters, 9 (3), 23-30 (in Chinese with an English abstract)
Yao, T. D., Liu, X. D., Wang, N. L. and Shi Y. F., 2000: Amplitude of climatic changes in Qinghai-Tibetan Plateau, Chinese Science Bulletin. 45(1), 98-106.
Yasukevich, V. V. and Semenov, S. M., 2004: Simulation of Climate-induced Changes in Natural Habitats of Malaria in Russia and Neighboring Countries, In Proceedings of the Intl. Conf. on Climate Change and Public Health in Russia, April 5-6, 2004, Moscow [Editors: Prof. N.F. Izmerov, Prof. B.A. Revich and Prof. E.I. Korenberg], pp.147-153.
Ye, B.S., Lai Z.M., Shi Y.F., 1996: The Effect of Climate Change on Runoff in the Yili River in the Tianshan Mountains, Journal of Glaciology and Geocryology,18(1):29-36.
Ye, J.L., Chen Z.H., Gong D.Y., Wang S.W., 1998: Characteristics of Seasonal Precipitation

Anomalies in China for 1880-1996, Quarterly Journal of Applied Meteorology, Vol 9 (S): 57-64.

Yin, Y.Y., Q.L. Miao and G.S. Tian, 2003: Climate change and regional sustainable development. Scince Press, Beijing, New York, 224 pp.

Yoshikawa, K. and L.D. Hinzman, 2003: Shrinking thermokarst ponds and groundwater dynamics in discontinuous permafrost near Council, Alaska, Permafrost and Periglacial Processes, 14(2): 151-160.

Yoshino, M., 1996: Change of global environment and insurance, Saigaino-kennkyuu, 26, 84-100 (in Japanese).

Yoshio, M. and M. Ishii, 1998: Geographical variation of pupal diapause in the Papilio memnon L. (Lepidoptera: Papilionidae), great mormon butterfly, in Western Japan, Appl. Entomol. Zool. 33(2), 281-288.

Yoshio, M. and M. Ishii, 2001: Relationship between cold hardiness and northward invasion in the great mormon butterfly, Papilio memnon L. (Lepidoptera: Papilionidae) in Japan. Appl. Entomol. Zool. 36(3), 329-335.

Zafar, Adeel, 2005: Training and Capacity Building for Managing Our Mangroves Resources – UNU's Role to Meet Regional Challenges, Environment & Sustainable Development Programme, Technical Notes of United Nations University, Tokyo, Japan.

Zalikhanov, M., 2004: Climate change and sustainable development in the Russian Federation, in Proc. of World Climate Change Conference, Moscow, 29 September – 3 October 2003, 466-477.

Zbigniew, Jaworowski, 2003: Solar Cycles not CO_2 determine Climate, 21st Century Science and Technology, Winter 2003-2004, Vol. 16, No. 4, pp.52-65.

Zeqiang, F., C. Yunlong, Y. Youxiao and D. Erfu, 2001: Research on the relationship of cultivated land change and food security in China. Journal of Natural Resources, 16 (4):313-319.

Zhai, P. M. and X. Pan, 2003: Trends in temperature extremes during 1951-1999 in China, Geophys. Res. Letters, 30.

Zhai, P. M., 2004: Climate change and meteorological disasters. Science and Technology Review, 193(7), 11-14

Zhai, P. M., A. Sun, F. Ren, X. Liu, B. Gao and Q. Zhang, 1999: Changes of Climate Extremes in China. Climatic Change, 42, 203-218.

Zhang, J. W. and B.L. Du, 2000: The trend of tidal range enlarging along the coast of the Yellow Sea. Marine Science Bulletin, 19(1), 1-9.

Zhang, Q. and G. Gao, 2004: The spatial and temporal features of drought and flood disasters in the past 50 years and monitoring and warning services in China. Science and Technology Reviews, 7, 21-24.

Zhang, X. S. and Liu, C.Y., 1994: Prospect of Vegetation Change under the Global Change on Qinghai-Tibetan Plateau, in Global Change and Ecosystem, Sciences and Technology Press, Shanghai, pp.17-26.

Zhang, Y., W. Chen and J. Cihlar, 2003: A process-based model for quantifying the impact of climate change on permafrost thermal regimes, Jr Geophys Res., 108(D22), 4695 doi:10.1029/2002JD003354.

Zhao, L., C.L. Ping, D. Yang, G. Cheng, Y. Ding, and S. Liu, 2004: Changes of climate and seasonally frozen ground over the past 30 years in Qinghai–Xizang (Tibetan) Plateau, China. Global and Planetary Change 43, 19–31.

Zhou, X.N., Yang G.J., Sun L.P., 2002: Potential Impacts of Global Climate Change on Spread of Schistosomiasis Disease, China Journal of Epidemiology, 23(2), 83-86.

Zhou, Y. H., 2003: Characteristics of weather and climate during drought periods in South China. Journal of Applied Meteorological Science, 14, Suppliment, 118-125.

Zolotov, P.A. and Caliberny, 2004: Human Physiological Functions and Public Health Ultra-Continental Climate, In Proceedings of the Intl. Conf. on Climate Change and Public Health in Russia, April 5-6, 2004, Moscow [Editors: Prof. N.F. Izmerov, Prof. B.A. Revich and Prof. E.I. Korenberg], 212-

222.