10

Asia

Coordinating Lead Authors:

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

Lead Authors:

Yurij Anokhin (Russia), Batima Punsalmaa (Mongolia), Yasushi Honda (Japan), Mostafa Jafari (Iran), Congxian Li (China), Nguyen Huu Ninh (Vietnam)

Contributing Authors:

Shiv D. Atri (India), Joseph Canadell (Australia), Seita Emori (Japan), Daidu Fan (China), Hui Ju (China), Shuangcheng Li (China), Tushar K. Moulik (India), Faizal Parish (Malaysia), Yoshiki Saito (Japan), Ashok K. Sharma (India), Kiyoshi Takahashi (Japan), Tran Viet Lien (Vietnam), Qiaomin Zhang (China)

Review Editors:

Daniel Murdiyarso (Indonesia), Shuzo Nishioka (Japan)

This chapter should be cited as:

Cruz, R.V., H. Harasawa, M. Lal, S. Wu, Y. Anokhin, B. Punsalmaa, Y. Honda, M. Jafari, C. Li and N. Huu Ninh, 2007: Asia. *Climate Change 2007: Impacts, Adaptation and Vulnerability*. *Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 469-506.

Table of Contents

Executive summary

New evidences show that climate change has affected many sectors in Asia (medium confidence).
The crop yield in many countries of Asia has declined, partly due to rising temperatures and extreme weather events. The retreat of glaciers and permafrost in Asia in recent years is unprecedented as a consequence of warming. The frequency of occurrence of climate-induced diseases and heat stress in Central, East, South and South-East Asia has increased with rising temperatures and rainfall variability. Observed changes in terrestrial and marine ecosystems have become more pronounced (medium confidence). [10.2.3, 10.2.4]

Future climate change is likely to affect agriculture, risk of hunger and water resource scarcity with enhanced climate variability and more rapid melting of glaciers (medium confidence).
About 2.5 to 10% decrease in crop yield is projected for parts of Asia in 2020s and 5 to 30% decrease in 2050s compared with 1990 levels without CO_2 effects (medium confidence) [10.4.1.1]. Freshwater availability in Central, South, East and South-East Asia, particularly in large river basins such as Changjiang, is likely to decrease due to climate change, along with population growth and rising standard of living that could adversely affect more than a billion people in Asia by the 2050s (high confidence) [10.4.2]. It is estimated that under the full range of Special Report on Emissions Scenarios (SRES) scenarios, 120 million to 1.2 billion will experience increased water stress by the 2020s, and by the 2050s the number will range from 185 to 981 million people (high confidence) [10.4.2.3]. Accelerated glacier melt is likely to cause increase in the number and severity of glacial melt-related floods, slope destabilisation and a decrease in river flows as glaciers recede (medium confidence) [10.2.4.2, 10.4.2.1]. An additional 49 million, 132 million and 266 million people of Asia, projected under A2 scenario without carbon fertilisation, could be at risk of hunger by 2020, 2050 and 2080, respectively (medium confidence) [10.4.1.4].

Marine and coastal ecosystems in Asia are likely to be affected by sea-level rise and temperature increases (high confidence).
Projected sea-level rise is very likely to result in significant losses of coastal ecosystems and a million or so people along the coasts of South and South-East Asia will likely be at risk from flooding (high confidence) [10.4.3.1]. Sea-water intrusion due to sea-level rise and declining river runoff is likely to increase the habitat of brackish water fisheries but coastal inundation is likely to seriously affect the aquaculture industry and infrastructure particularly in heavily-populated megadeltas (high confidence) [10.4.1.3, 10.4.3.2]. Stability of wetlands, mangroves and coral reefs around Asia is likely to be increasingly threatened (high confidence) [10.4.3.2, 10.6.1]. Recent risk analysis of coral reef suggests that between 24% and 30% of the reefs in Asia are likely to be lost during the next 10 years and 30 years, respectively (medium confidence) [10.4.3.2].

Climate change is likely to affect forest expansion and migration, and exacerbate threats to biodiversity resulting from land use/cover change and population pressure in most of Asia (medium confidence).
Increased risk of extinction for many flora and fauna species in Asia is likely as a result of the synergistic effects of climate change and habitat fragmentation (medium confidence) [10.4.4.1]. In North Asia, forest growth and northward shift in the extent of boreal forest is likely (medium confidence) [10.4.4]. The frequency and extent of forest fires in North Asia is likely to increase in the future due to climate change that could likely limit forest expansion (medium confidence) [10.4.4].

Future climate change is likely to continue to adversely affect human health in Asia (high confidence).
Increases in endemic morbidity and mortality due to diarrhoeal disease primarily associated with climate change are expected in South and South-East Asia (high confidence). Increases in coastal water temperature would exacerbate the abundance and/or toxicity of cholera in south Asia (high confidence). Natural habitats of vector-borne and water-borne diseases in north Asia are likely to expand in the future (medium confidence). [10.4.5]

Multiple stresses in Asia will be compounded further due to climate change (high confidence).
It is likely that climate change will impinge on sustainable development of most developing countries of Asia as it compounds the pressures on natural resources and the environment associated with rapid urbanisation, industrialisation and economic development. Mainstreaming sustainable development policies and the inclusion of climate-proofing concepts in national development initiatives are likely to reduce pressure on natural resources and improve management of environmental risks (high confidence) [10.7].

10.1 Summary of knowledge assessed in the Third Assessment Report

10.1.1 Climate change impacts in Asia

Climate change and variability.

Extreme weather events in Asia were reported to provide evidence of increases in the intensity or frequency on regional scales throughout the 20th century. The Third Assessment Report (TAR) predicted 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 (Lal et al., 2001a). The rise in surface air temperature was projected to be most pronounced over boreal Asia in all seasons.

Climate change impacts.

An enhanced hydrological cycle and an increase in area-averaged annual mean rainfall over Asia were projected. 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 periodic severe water stress conditions. Increased rainfall intensity, particularly during the summer monsoon, could increase flood-prone areas in temperate and tropical Asia.

10.1.2 Vulnerabilities and adaptive strategies

Vulnerable sectors. 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 processes of permafrost degradation resulting from global warming strengthen the vulnerability of all relevant climate-dependent sectors affecting the economy in high-latitude Asia.

Vulnerable regions. 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 landslides, 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 is also 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 stability of mangroves and coral reefs around Asia would be put at risk.

Adaptation strategies. Increases 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 could substantially enhance social capital and reduce the vulnerability of developing countries of Asia to climate change. Development and implementation of incremental adaptation strategies and policies to exploit 'no regret' measures and 'win-win' options were to be preferred over other options. Adaptations to deal with sea-level rise, potentially more intense cyclones, and threats to ecosystems and biodiversity were recommended as high priority actions in temperate and tropical Asian countries. It was suggested that the design of an appropriate adaptation programme in any Asian country must be based on comparison of damages avoided with costs of adaptation.

Advances since the TAR. Aside from new knowledge on the current trends in climate variability and change – including the extreme weather events – more information is now available that confirms most of the key findings on impacts, vulnerabilities and adaptations for Asia. This chapter assesses the state of knowledge on impacts, vulnerabilities and adaptations for various regions in Asia.

10.2 Current sensitivity and vulnerability

10.2.1 Asia: regional characteristics

Asia is the most populous continent (Figure 10.1). Its total population in 2002 was reported to be about 3,902 million, of which almost 61% is rural and 38.5% lives within 100 km of the coast (Table 10.1). The coastline of Asia is 283,188 km long (Duedall and Maul, 2005). In this report, Asia is divided into seven sub-regions, namely North Asia, Central Asia, West Asia, Tibetan Plateau, East Asia, South Asia and South-East Asia (for further details on boundaries of these sub-regions see Table 10.5).

North Asia, located in the Boreal climatic zone, is the coldest region of the northern hemisphere in winter (ACIA, 2005). One of the world's largest and oldest lakes, Baikal, located in this region contains as much as 23,000 km^3 of freshwater and holds nearly 20% of the world surface freshwater resources (Izrael and Anokhin, 2000). *Central* and *West Asia* include several countries of predominantly arid and semi-arid region. *Tibetan Plateau* can be divided into the eastern part (forest region), the northern part (open grassland), and the southern and central part (agricultural region). *East Asia* stretches in the east-west direction to about 5,000 km and in the north-south to about 3,000 km including part of China, Japan and Korea. *South Asia* is physiographically diverse and ecologically rich in natural and crop-related biodiversity. The region has five of the 20 megacities of the world (UN-HABITAT, 2004). *South-East Asia* is characterised by tropical rainforest, monsoon climates with high and constant rainfall, heavily-leached soils, and diverse ethnic groups. Table 10.1 lists the key socio-economic and natural resource features of the countries of Asia (WRI, 2003; FAO, 2004a, b, c; World Bank, 2005).

10.2.2 Observed climate trends, variability and extreme events

Past and present climate trends and variability in Asia are generally characterised by increasing surface air temperature which is more pronounced during winter than in summer. Increasing trends have been observed across the seven sub-regions of Asia. The observed increases in some parts of Asia during recent decades ranged between less than 1°C to 3°C per century. Increases in surface temperature are most pronounced in North Asia (Savelieva et al., 2000; Izrael et al., 2002a; Climate Change in Russia, 2003; Gruza and Rankova, 2004).

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 are observed in Russia, North-East and North China, coastal belts and arid plains of Pakistan, parts of North-East India, Indonesia, Philippines and some areas in Japan. Annual mean rainfall exhibits increasing trends in Western China, Changjiang Valley and the South-Eastern coast of China, Arabian Peninsula, Bangladesh and along the western coasts of the Philippines. Table 10.2 lists more details on observed characteristics in surface air temperature and rainfall in Asian sub-regions.

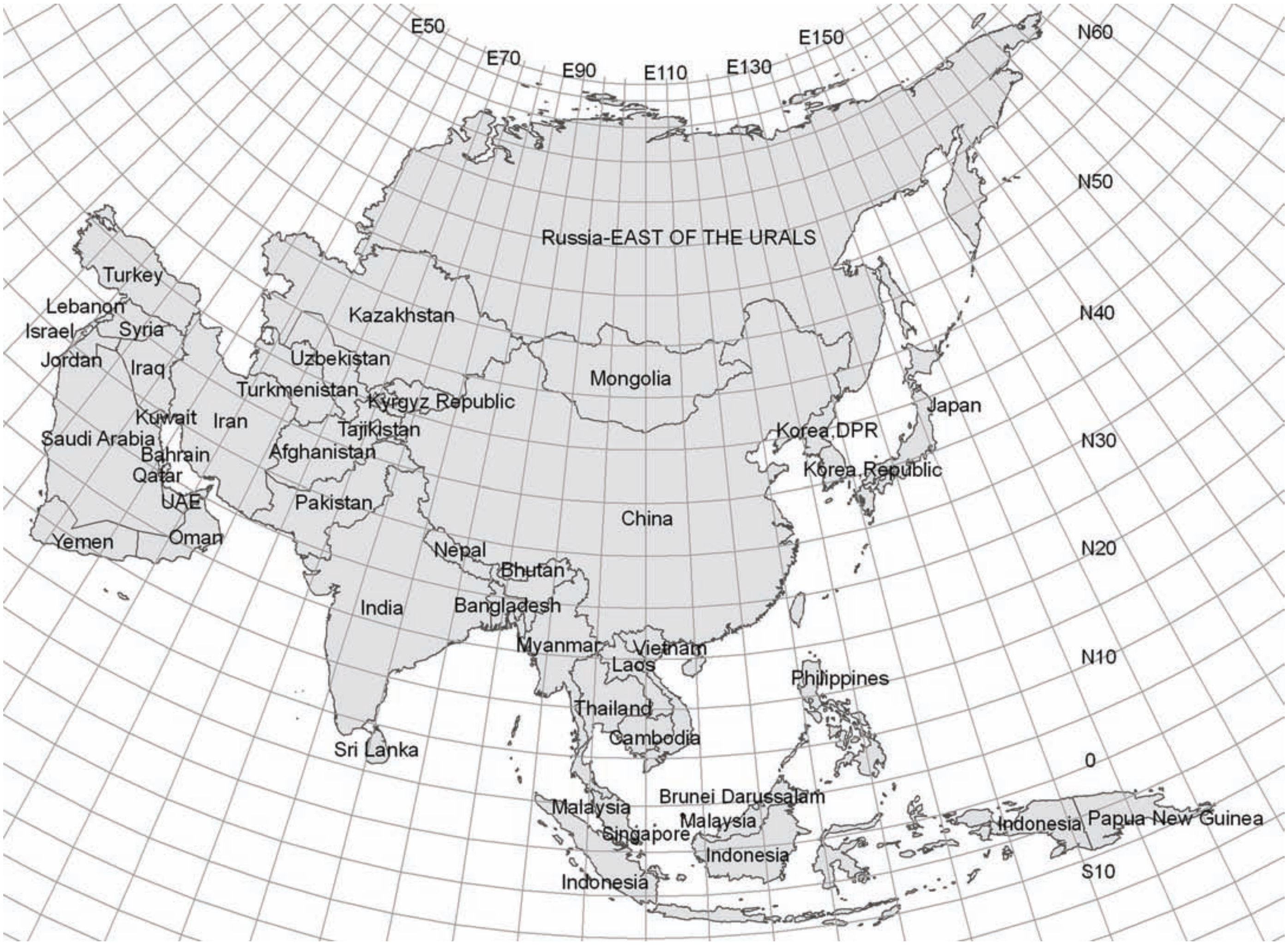


Figure 10.1. *Location of countries covered under Asia included in this chapter.*

10.2.3 Observed changes in extreme climatic events

New evidence on recent trends, particularly on the increasing tendency in the intensity and frequency of extreme weather events in Asia over the last century and into the 21st century, is briefly discussed below and summarised in Table 10.3. In South-East Asia, extreme weather events associated with El-Niño were reported to be more frequent and intense in the past 20 years (Trenberth and Hoar, 1997; Aldhous, 2004).

Significantly longer heatwave duration has been observed in many countries of Asia, as indicated by pronounced warming trends and several cases of severe heatwaves (De and Mukhopadhyay, 1998; Kawahara and Yamazaki, 1999; Zhai et al., 1999; Lal, 2003; Zhai and Pan, 2003; Ryoo et al., 2004; Batima et al., 2005a; Cruz et al., 2006; Tran et al., 2005).

Generally, the frequency of occurrence of more intense rainfall events in many parts of Asia has increased, causing severe floods, landslides, and debris and mud flows, while the number of rainy days and total annual amount of precipitation has decreased (Zhai et al., 1999; Khan et al., 2000; Shrestha et al., 2000; Izrael and Anokhin, 2001; Mirza, 2002; Kajiwara et al., 2003; Lal, 2003; Min et al., 2003; Ruosteenoja et al., 2003; Zhai and Pan, 2003; Gruza and Rankova, 2004; Zhai, 2004). However, there are reports that the frequency of extreme rainfall in some countries has exhibited a decreasing tendency (Manton et al., 2001; Kanai et al., 2004).

Increasing frequency and intensity of droughts in many parts of Asia are attributed largely to a rise in temperature, particularly during the summer and normally drier months, and during ENSO events (Webster et al., 1998; Duong, 2000; PAGASA, 2001; Lal, 2002, 2003; Batima, 2003; Gruza and Rankova, 2004; Natsagdorj et al., 2005).

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 damage caused by intense cyclones has risen significantly in the affected countries, particularly India, China, Philippines, Japan, Vietnam and Cambodia, Iran and Tibetan Plateau (PAGASA, 2001; ABI, 2005; GCOS, 2005a, b).

Table 10.1. *Key information on socio-economics and natural resources of the Asian countries*

Country	Total population (1,000 inhab) 2004	2004 GDP per capita (constant US$2000)	Land area* (1,000ha) 2002	Arable land and permanent crops (1,000 ha) 2002	Arable land (1,000 ha) 2002	Total forest area, 2005 (1,000ha)	Percent of forest cover (FAO, 2005)	Natural RWR**, 2002 (per capita m^3)	Water resources: total renewable per capita (actual) (m^3/inhab/yr) 1998 to 2002	Average production of cereals, 2005 (1,000t)	Annual fish and fishery products (kg/capita) (2002)
Reference	a	b	c	c	c	d	d	e	e	f	g
Afghanistan	24926	x	65209	8045	7910	867	1.3	2790	2835	4115	x
Bahrain	739	13852	71	6	2	x	x	x	164	0	x
Bangladesh	149664	402	13017	8429	7997	871	6.7	8444	8418	41586	11
Bhutan	2325	695	4700	128	108	3195	68	43214	43379	127	x
Brunei Darussalam	366	x	527	17	12	278	52.8	x	24286	1	x
Cambodia	14482	339	17652	3807	3700	10447	59.2	34561	34476	4458	28
China	1320892	1323	932743	154353	142618	197290	21.2	2186	2172	427613	26
India	1081229	538	297319	169800	160000	67701	22.8	1822	1807	235913	5
Indonesia	222611	906	181157	33700	20500	88495	48.8	13046	13070	65998	21
Iran, Islamic Rep	69788	1885	163620	17088	15020	11075	6.8	1900	2020	21510	5
Iraq	25856	x	43737	6019	5750	822	1.9	3111	3077	3934	x
Israel	6560	17788	2171	427	341	171	8.3	265	265	341	22
Japan	127800	38609	36450	4762	4418	24868	68.2	3372	3373	12426	66
Jordan	5614	1940	8824	400	295	83	0.9	169	165	83	5
Kazakhstan	15403	1818	269970	22799	22663	3337	1.2	6839	7086	13768	4
Korea, DPR	22776	x	12041	2900	2700	6	0.3	3415	3422	4461	8
Korea, Republic	47951	12752	9873	1863	1663	869	4.5	1471	1470	6776	59
Kuwait	2595	17674	1782	18	15	16142	69.9	10	8	3	9
Kyrgyz Republic	5208	325	19180	1363	1308	136	13.3	4078	4062	1625	1
Laos	5787	378	23080	1001	920	20890	63.6	60318	60327	2560	15
Lebanon	3708	5606	1023	313	170	10252	6.5	1220	1226	145	12
Malaysia	24876	4290	32855	7585	1800	32222	49	25178	24202	2290	57
Mongolia	2630	462	156650	1200	1198	0	0	13451	13599	75	0
Myanmar	50101	x	67658	10611	9862	3636	25.4	21358	21403	25639	19
Nepal	25725	231	14300	2480	2360	x	x	8703	8542	7577	1
Oman	2935	8961	30950	81	38	1902	2.5	364	356	6	x
Pakistan	157315	566	77088	22280	21608	29437	65	2812	1485	32972	2
Papua New Guinea	5836	604	45286	870	220	7162	24	x	143394	11	x
Philippines	81408	1085	29817	10700	5700	x	x	6093	6096	19865	29
Qatar	619	x	1100	21	18	6265	63.5	x	88	7	x
Russia - E. of Urals	142397	2286	1638098	125300	123465	808790	47.9	31354	31283	76420	19
Saudi Arabia	24919	8974	214969	3793	3600	2728	1.3	111	102	2590	7
Singapore	4315	24164	67	2	1	2	3.4	x	143	0	x
Sri Lanka	19218	962	6463	1916	916	1933	29.9	2592	2644	3172	22
Syrian Arab Rep	18223	1115	18378	5421	4593	461	2.5	1541	1511	5620	3
Tajikistan	6298	223	13996	1057	930	410	2.9	2587	2579	859	0
Thailand	63465	2356	51089	19367	15867	14520	28.4	6371	6591	31490	31
Turkey	72320	3197	76963	26579	23994	10175	13.2	3344	3037	34570	7
Turkmenistan	4940	x	46993	1915	1850	4127	8.8	5015	5156	3035	3
UAE	3051	x	8360	266	75	312	3.7	56	51	0	24
Uzbekistan	26479	639	42540	4827	4484	3295	8	1968	1961	6182	0
Vietnam	82481	502	32549	8813	6600	12931	39.7	11109	11102	39841	18
Yemen	20733	534	52797	1669	1538	549	1	x	212	554	6

* Land area: total land area excluding area under inland water bodies.
** RWR: renewable water resources.

Data sources:
a: http://faostat.fao.org/site/429/default.aspx
b: http://earthtrends.wri.org/searchable_db/index.php?theme=5&variable_ID=640&action=select_countries
c: http://faostat.fao.org/site/418/default.aspx
d: www.fao.org/forestry/foris/webview/forestry2/index.jsp?siteId=6833&sitetreeId=32006&langId=1&geoId=0
e: www.fao.org/ag/agl/aglw/aquastat/dbase/index.htm
f: http://faostat.fao.org/site/408/DesktopDefault.aspx?PageID=408
g: http://earthtrends.wri.org/pdf_library/data_tables/ene5_2005.pdf#search=%22WRI%20Resource%20Consumption%202005%22

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 and winter	Highly variable, decrease during 1951 to 1995, increase in last decade	Savelieva et al., 2000; Peterson et al., 2002; Gruza and Rankova, 2004
	Mongolia	1.8°C rise in last 60 years, most pronounced in winter	7.5% decrease in summer and 9% increase in winter	Batima et al., 2005a; Natsagdorj et al., 2005
Central Asia	Regional mean	1 to 2°C rise in temperature per century	No clear trend during 1900 to 1996.	Peterson et al., 2002
	North-West China	0.7°C increase in mean annual temperature from 1961 to 2000	Between 22% and 33% increase in rainfall	Shi et al., 2002
Tibetan Plateau	Regional mean	0.16 and 0.32°C per decade increase in annual and winter temperatures, respectively	Generally increasing in north-east region	Liu et al., 1998; Yao et al., 2000; Liu and Chen, 2001; Cai et al., 2003; Du and Ma, 2004; Zhao et al., 2004
West Asia (Middle East)	Iran	During 1951 to 2003 several stations in different climatological zones of Iran reported significant decrease in frost days due to rise in surface temperature	Some stations show a decreasing trend in precipitation (Anzali, Tabriz, Zahedan) while others (Mashad, Shiraz) have reported increasing trends	IRIMO, 2006a, b; Rahimzadeh, 2006
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 declined in past decade in North-East and North China, increase in Western China, Changjiang River and along south-east coast	Zhai et al., 1999; Hu et al., 2003; Zhai and Pan, 2003
	Japan	About 1.0°C rise in 20th century, 2 to 3°C rise in large cities	No significant trend in the 20th century although fluctuations increased	Ichikawa, 2004; Japan Meteorological Agency, 2005
	Korea	0.23°C rise in annual mean temperature per decade, increase in 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 trends in annual mean temperature, warming more pronounced during post monsoon and winter	Increase in extreme rains in north-west during summer monsoon in recent decades, lower number of rainy days along east coast	Kripalani et al., 1996; Lal et al., 1996; Lal et al., 2001b; Singh and Sontakke, 2002; Lal, 2003
	Nepal	0.09°C per year in Himalayas and 0.04°C in Terai region, more in winter	No distinct long-term trends in precipitation records for 1948 to 1994	Shrestha et al., 2000; Bhadra, 2002; Shrestha, 2004
	Pakistan	0.6 to 1.0°C rise in mean temperature in coastal areas since early 1900s	10 to 15% decrease in coastal belt and hyper arid plains, increase in summer and winter precipitation over the last 40 years in northern Pakistan	Farooq and Khan, 2004
	Bangladesh	An increasing trend of about 1°C in May and 0.5°C in November during the 14 year period from 1985 to 1998	Decadal rain anomalies above long term averages since 1960s	Mirza and Dixit, 1997; Khan et al., 2000; Mirza, 2002
	Sri Lanka	0.016°C increase per year between 1961 to 90 over entire country, 2°C increase per year in central highlands	Increase trend in February and decrease trend in June	Chandrapala and Fernando, 1995; Chandrapala, 1996
S-E Asia	General	0.1 to 0.3°C increase per decade reported between 1951 to 2000	Decreasing trend between 1961 and 1998. Number of rainy days have declined throughout S-E Asia	Manton et al., 2001
	Indonesia	Homogeneous temperature data were not available	Decline in rainfall in southern and increase in northern region	Manton et al., 2001; Boer and Faqih, 2004
	Philippines	Increase in mean annual, maximum and minimum temperatures by 0.14°C between 1971 to 2000	Increase in annual mean rainfall since 1980s and in number of rainy days since 1990s, increase in inter-annual variability of onset of rainfall	PAGASA, 2001; Cruz et al., 2006

10.2.4 Impacts of observed changes in climate trends, variability and extreme events

10.2.4.1 Agriculture and food production

Production of rice, maize and wheat in the past few decades has declined in many parts of Asia due to increasing water stress arising partly from increasing temperature, increasing frequency of El Niño and reduction in the number of rainy days (Wijeratne, 1996; Aggarwal et al., 2000; Jin et al., 2001; Fischer et al., 2002; Tao et al., 2003a; Tao et al., 2004). In a study at the International Rice Research Institute, the yield of rice was observed to decrease by 10% for every 1°C increase in growing-season minimum temperature (Peng et al., 2004). A decline in potentially good agricultural land in East Asia and substantial increases in suitable areas and production potentials in currently cultivated land in Central Asia have also been reported (Fischer et al., 2002). Climate change could make it more difficult than it is already to step up the agricultural production to meet the growing demands in Russia (Izrael and Sirotenko, 2003) and other developing countries in Asia.

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

Country/Region	Key trend	Reference
Heatwaves		
Russia	Heatwaves broke past 22-year record in May 2005	Shein, 2006
Mongolia	Heatwave duration has increased by 8 to 18 days in last 40 years; coldwave duration has shortened by 13.3 days	Batima et al., 2005a
China	Increase in frequency of short duration heatwaves in recent decade, increasing warmer days and nights in recent decades	Zhai et al., 1999; Zhai and Pan, 2003
Japan	Increasing incidences of daily maximum temperature >35°C, decrease in extremely low temperature	Kawahara and Yamazaki, 1999; Japan Meteorological Agency, 2005
Korea	Increasing frequency of extreme maximum temperatures with higher values in 1980s and 1990s; decrease in frequency of record low temperatures during 1958 to 2001	Ryoo et al., 2004
India	Frequency of hot days and multiple-day heatwave has increased in past century; increase in deaths due to heat stress in recent years	De and Mukhopadhyay, 1998; Lal, 2003
South-East Asia	Increase in hot days and warm nights and decrease in cold days and nights between 1961 and 1998	Manton et al., 2001; Cruz et al., 2006; Tran et al., 2005
Intense Rains and Floods		
Russia	Increase in heavy rains in western Russia and decrease in Siberia; increase in number of days with more than 10 mm rain; 50 to 70% increase in surface runoff in Siberia	Gruza et al., 1999; Izrael and Anokhin, 2001; Ruosteenoja et al., 2003; Gruza and Rankova, 2004
China	Increasing frequency of extreme rains in western and southern parts including Changjiang river, and decrease in northern regions; more floods in Changjiang river in past decade; more frequent floods in North-East China since 1990s; more intense summer rains in East China; severe flood in 1999; seven-fold increase in frequency of floods since 1950s	Zhai et al., 1999; Ding and Pan, 2002; Zhai and Pan, 2003; Zhai, 2004
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; increase in maximum rainfall during 1961 to 2000 based on records from 120 stations	Kawahara and Yamazaki, 1999; Isobe, 2002; Kajiwara et al., 2003; Kanai et al., 2004
South Asia	Serious and recurrent floods in Bangladesh, Nepal and north-east states of India during 2002, 2003 and 2004; a record 944 mm of rainfall in Mumbai, India on 26 to 27 July 2005 led to loss of over 1,000 lives with loss of more than US$250 million; floods in Surat, Barmer and in Srinagar during summer monsoon season of 2006; 17 May 2003 floods in southern province of Sri Lanka were triggered by 730 mm rain	India Meteorological Department, 2002 to 2006; Dartmouth Flood Observatory, 2003.
South-East 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/WFP, 2000; Environment News Service, 2002; FAO, 2004a; Cruz et al., 2006; Tran et al., 2005
Droughts		
Russia	Decreasing rain and increasing temperature by over 1°C have caused droughts; 27 major droughts in 20th century have been reported	Golubev and Dronin, 2003; Izrael and Sirotenko, 2003
Mongolia	Increase in frequency and intensity of droughts in recent years; droughts in 1999 to 2002 affected 70% of grassland and killed 12 million livestock	Batima, 2003; Natsagdorj et al., 2005
China	Increase in area affected by drought has exceeded 6.7 Mha since 2000 in Beijing, Hebei Province, Shanxi Province, Inner Mongolia and North China; increase in dust storm affected area	Chen et al., 2001; Yoshino, 2000, 2002; Zhou, 2003
South Asia	50% of droughts associated with El Niño; consecutive droughts in 1999 and 2000 in Pakistan and N-W India led to sharp decline in watertables; consecutive droughts between 2000 and 2002 caused crop failures, mass starvation and affected ~11 million people in Orissa; droughts in N-E India during summer monsoon of 2006	Webster et al., 1998; Lal, 2003; India Meteorological Department, 2006
South-East Asia	Droughts normally associated with ENSO years in Myanmar, Laos, Philippines, Indonesia and Vietnam; droughts in 1997 to 98 caused massive crop failures and water shortages and forest fires in various parts of Philippines, Laos and Indonesia	Duong, 2000; Kelly and Adger, 2000; Glantz, 2001; PAGASA, 2001
Cyclones/Typhoons		
Philippines	On an average, 20 cyclones cross the Philippines Area of Responsibility with about 8 to 9 landfall each year; with an increase of 4.2 in the frequency of cyclones entering PAR during the period 1990 to 2003	PAGASA, 2001
China	Number and intensity of strong cyclones increased since 1950s; 21 extreme storm surges in 1950 to 2004 of which 14 occurred during 1986 to 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 is increasing causing severe floods in terms of damages to life and property	Lal, 2001, 2003
Japan	Number of tropical storms has two peaks, one in mid 1960s and another in early 1990s, average after 1990 and often lower than historical average	Japan Meteorological Agency, 2005

Table 10.4. *Recent trends in permafrost temperatures measured at different locations (modified from Romanovsky et al., 2002 and Izrael et al., 2006)*

Country	Region	Permafrost temperature change/trends	References
Russia	East Siberia (1.6 to 3.2 m), 1960 to 1992	+0.03°C/year	Romanovsky et al., 2001
	West Siberia (10 m), 1960 to 2005	+0.6°C/year	Izrael et al., 2006
China	Qinghai-Tibet Plateau (1975 to 1989)	+0.2 to +0.3°C	Cheng and Wu, 2007
Kazakhstan	Northern Tian Shan (1973 to 2003)	+0.2° to +0.6°C	Marchenko, 2002
Mongolia	Khentei and Khangai Mountains, Lake Hovsgol (1973 to 2003)	+0.3° to +0.6°C	Sharkhuu, 2003

10.2.4.2 Hydrology and water resources

Rapid thawing of permafrost (Table 10.4) and decrease in depths of frozen soils (4 to 5 m in Tibet according to Wang et al., 2004b) due largely to rising temperature has threatened many cities and human settlements, has caused more frequent landslides and degeneration of some forest ecosystems, and has resulted in increased lake-water levels in the permafrost region of Asia (Osterkamp et al., 2000; Guo et al., 2001; Izrael and Anokhin, 2001; Jorgenson et al., 2001; Izrael et al., 2002b; Fedorov and Konstantinov, 2003; Gavriliev and Efremov, 2003; Melnikov and Revson, 2003; Nelson, 2003; ACIA, 2005).

In drier parts of Asia, melting glaciers account for over 10% of freshwater supplies (Meshcherskaya and Blazhevich, 1990; Fitzharris, 1996; Meier, 1998). Glaciers in Asia are melting faster in recent years than before, as reported in Central Asia, Western Mongolia and North-West China, particularly the Zerafshan glacier, the Abramov glacier and the glaciers on the Tibetan Plateau (see Section 10.6.2) (Pu et al., 2004). As a result of rapid melting of glaciers, glacial runoff and frequency of glacial lake outbursts causing mudflows and avalanches have increased (Bhadra, 2002; WWF, 2005). A recent study in northern Pakistan, however, suggests that glaciers in the Indus Valley region may be expanding, due to increases in winter precipitation over western Himalayas during the past 40 years (Archer and Fowler, 2004).

In parts of China, the rise in temperature and decreases in precipitation (Ma and Fu, 2003; Wang and Zhai, 2003), along with increasing water use have caused water shortages that led to drying up of lakes and rivers (Liu et al., 2006; Wang and Jin, 2006). In India, Pakistan, Nepal and Bangladesh, water shortages have been attributed to rapid urbanisation and industrialisation, population growth and inefficient water use, which are aggravated by changing climate and its adverse impacts on demand, supply and water quality. In arid Central and West Asia, changes in climate and its variability continue to challenge the ability of countries in the arid and semi-arid region to meet the growing demands for water (Abu-Taleb, 2000; UNEP, 2002; Bou-Zeid and El-Fadel, 2002; Ragab and Prudhomme, 2002). Decreasing precipitation and increasing temperature commonly associated with ENSO have been reported to increase water shortage, particularly in parts of Asia where water resources are already under stress from growing water demands and inefficiencies in water use (Manton et al., 2001).

10.2.4.3 Oceans and coastal zones

Global warming and sea-level rise in the coastal zone of Boreal Asia have influenced sea-ice formation and decay, thermo-abrasion process, permafrost and the time of river freeze-up and break-up in recent decades (ACIA, 2005; Leont'yev, 2004). The coastlines in monsoon Asia are cyclone-prone with ~42% of the world's total tropical cyclones occurring in this region (Ali, 1999). The combined extreme climatic and non climatic events caused coastal flooding, resulting in substantial economic losses and fatalities (Yang, 2000; Li et al., 2004a). Wetlands in the major river deltas have been significantly altered in recent years due to large scale sedimentation, land-use conversion, logging and human settlement (Lu, 2003). Coastal erosion in Asia has led to loss of lands at rates dependent on varying regional tectonic activities, sediment supply and sea-level rise (Sin, 2000). Salt water 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 have also resulted in sea-water intrusion in the coastal plains of China (Ding et al., 2004).

Over 34% of the vast and diverse coral reefs of Asia that are of immense ecological and economic importance to this region (Spalding et al., 2001; Burke et al., 2002; Zafar, 2005) particularly in South, South-East and East Asia are reported to have been lost in 1998, largely due to coral bleaching induced by the 1997/98 El Niño event (Wilkinson, 2000; Arceo et al., 2001; Wilkinson, 2002; Ministry of the Environment and Japanese Coral Reef Society, 2004; Yamano and Tamura, 2004). The destructive effects of climate change compound the human-induced damages on the corals in this region. A substantial portion of the vast mangroves in South and South-East Asian regions has also been reportedly lost during the last 50 years of the 20th century, largely attributed to human activities (Zafar, 2005). Evidence of the impacts of climate-related factors on mangroves remain limited to the severe destruction of mangroves due to reduction of freshwater flows and salt-water intrusion in the Indus delta and Bangladesh (IUCN, 2003a).

10.2.4.4 Natural ecosystems

Increasing intensity and spread of forest fires in Asia were observed in the past 20 years, largely attributed to the rise in temperature and decline in precipitation in combination with increasing intensity of land uses (Page et al., 2002; De Grandi et al., 2003; Goldammer et al., 2003; FFARF, 2004; Isaev et al., 2004; Murdiyarso et al., 2004; Shoigu, 2004; Vorobyov, 2004; Achard et al., 2005; Murdiyarso and Adiningsih, 2006). During the last decade, 12,000 to 38,000 wild fires annually hit the boreal forests in North Asia affecting some 0.3 to 3 million hectares (Dumnov et al., 2005; Malevski-Malevich et al., 2005; FNCRF, 2006). Recent studies have also shown a dramatic increase of fires in Siberian peatlands (of which 20 million ha were burnt in 2003) linked to increased human activities combined with changing climate conditions, particularly the increase in temperature. Fires in peatlands of Indonesia during the 1997 to 98 El Niño dry season affected over 2 million ha and emitted an estimated 0.81 to 2.57 PgC to the atmosphere (Page et al., 2002). In the past 10 years about 3 million ha of peatland in South-East Asia have been burnt, releasing between 3 to 5 PgC, and drainage of peat has affected an additional 6 million ha and released a further 1 to 2 PgC. As a consequence of a 17% decline in spring precipitation and a rise in surface temperature by 1.5°C during the last 60 years, the frequency and aerial extent of the forest and steppe fires in Mongolia have significantly increased over a period of 50 years (Erdnethuya, 2003). The 1997/98 ENSO event in Indonesia triggered forest and brush fires in 9.7 million hectares, with serious domestic and trans-boundary pollution consequences. Thousands of hectares of second growth and logged-over forests were also burned in the Philippines during the 1997/98 ENSO events (Glantz, 2001; PAGASA, 2001).

With the gradual reduction in rainfall during the growing season for grass, aridity in Central and West Asia has increased in recent years, reducing growth of grasslands and increasing bareness of the ground surface (Bou-Zeid and El-Fadel, 2002). 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).

Wetlands in Asia are being increasingly threatened by warmer climate in recent decades. The precipitation decline and droughts in most delta regions of Pakistan, Bangladesh, India and China have resulted in the drying up of wetlands and severe degradation of ecosystems. The recurrent droughts from 1999 to 2001, as well as the building of an 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).

10.2.4.5 Biodiversity

Biodiversity in Asia is being lost as a result of development activities and land degradation (especially overgrazing and deforestation), pollution, over-fishing, hunting, infrastructure development, species invasion, land-use change, climate change and the overuse of freshwater (UNEP, 2002; Gopal, 2003). Though evidence of climate-related biodiversity loss in Asia remains limited, a large number of plant and animal species are reported to be moving to higher latitudes and altitudes as a consequence of observed climate change in many parts of Asia in recent years (Yoshio and Ishii, 2001; IUCN, 2003a). Changes in the flowering date of Japanese Cherry, a decrease in alpine flora in Hokkaido and other high mountains and the expansion of the distribution of southern broad-leaved evergreen trees have also been reported (Oda and Ishii, 2001; Ichikawa, 2004; Kudo et al., 2004; Wada et al., 2004).

10.2.4.6 Human health

A large number of deaths due to heatwaves – mainly among the poor, elderly and labourers such as rural daily wage earners, agricultural workers and rickshaw pullers – have been reported in the Indian state of Andhra Pradesh, Orissa and elsewhere during the past five years (Lal, 2002). Serious health risks associated with extreme summer temperatures and heatwaves have also been reported in Siberian cities (Zolotov and Caliberny, 2004).

In South Asia, endemic morbidity and mortality due to diarrhoeal disease is linked to poverty and hygiene behaviour compounded by the effect of high temperatures on bacterial proliferation (Checkley et al., 2000). Diarrhoeal diseases and outbreaks of other infectious diseases (e.g., cholera, hepatitis, malaria, dengue fever) have been reported to be influenced by climate-related factors such as severe floods, ENSO-related droughts, sea-surface temperatures and rainfall in association with non-climatic factors such as poverty, lack of access to safe drinking water and poor sewerage system (Durkin et al., 1993; Akhtar and McMichael, 1996; Bouma and van der Kaay, 1996; Colwell, 1996; Bangs and Subianto, 1999; Lobitz et al., 2000; Pascual et al., 2000; Bouma and Pascual, 2001; Glantz, 2001; Pascual et al., 2002; Rodo et al., 2002).

10.3 Assumptions about future trends

10.3.1 Climate

Table 10.5 provides a snapshot of the projections on likely increase in area-averaged seasonal surface air temperature and percent change in area-averaged seasonal precipitation (with respect to the baseline period 1961 to 1990) for the seven sub-regions of Asia. The temperature projections for the 21st century, based on Fourth Assessment Report (AR4) Atmosphere-Ocean General Circulation Models (AOGCMs), and discussed in detail in Working Group I Chapter 11, suggest a significant acceleration of warming over that observed in the 20th century (Ruosteenoja et al., 2003; Christensen et al., 2007). Warming is least rapid, similar to the global mean warming, in South-East Asia, stronger over South Asia and East Asia and greatest in the continental interior of Asia (Central, West and North Asia). In general, projected warming over all sub-regions of Asia is higher during northern hemispheric winter than during summer for all time periods. The most pronounced warming is projected at high latitudes in North Asia. Recent modelling experiments suggest that the warming would be significant in Himalayan Highlands including the Tibetan Plateau and arid regions of Asia (Gao et al., 2003).

The consensus of AR4 models, as discussed in Chapter 2 and in Christensen et al. (2007) and confirmed in several studies using regional models (Lal, 2003; Rupa Kumar et al., 2003; Kwon et al., 2004; Boo et al., 2004; Japan Meteorological Agency, 2005; Kurihara et al., 2005), indicates an increase in annual precipitation in most of Asia during this century; the relative increase being largest and most consistent between models in North and East Asia. The sub-continental mean winter precipitation will very likely increase in northern Asia and the Tibetan Plateau and likely increase in West, Central, South-East and East Asia. Summer precipitation will likely increase in North, South, South-East and East Asia but decrease in West and Central Asia. The projected decrease in mean precipitation in Central Asia will be accompanied by an increase in the frequency of very dry spring, summer and autumn seasons. In South Asia, most of the AR4 models project a decrease of precipitation in December, January and February (DJF) and support earlier findings reported in Lal et al. (2001b).

An increase in occurrence of extreme weather events including heatwave and intense precipitation events is also projected in South Asia, East Asia, and South-East Asia (Emori et al., 2000; Kato et al., 2000; Sato, 2000; Lal, 2003; Rupa Kumar et al., 2003; Hasumi and Emori, 2004; Ichikawa, 2004; May, 2004b; Walsh, 2004; Japan Meteorological Agency, 2005; Kurihara et al., 2005) along with an increase in the interannual variability of daily precipitation in the Asian summer monsoon (Lal et al., 2000; May, 2004a; Giorgi and Bi, 2005). Results of regional climate model experiments for East Asia (Sato, 2000; Emori et al., 2000; Kato et al., 2000; Ichikawa, 2004; Japan Meteorological Agency, 2005; Kurihara et al., 2005) indicate that heatwave conditions over Japan are likely to be enhanced in the future (Figure 10.2). Extreme daily precipitation, including that associated with typhoon, would be further enhanced over Japan due to the increase in atmospheric moisture availability (Hasumi and Emori, 2004). The increases in annual temperature and precipitation over Japan are also projected regionally using regional climate model (Figure 10.3; Japan Meteorological Agency, 2005; Kurihara et al., 2005).

An increase of 10 to 20% in tropical cyclone intensities for a rise in sea-surface temperature of 2 to 4°C relative to the current threshold temperature is likewise projected in East Asia, South-East Asia and South Asia (Knutson and Tuleya, 2004). Amplification in storm-surge heights could 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 South-East Asian countries. The impacts of an increase in cyclone intensities in any location will be determined by any shift in the cyclone tracks (Kelly and Adger, 2000).

In coastal areas of Asia, the current rate of sea-level rise is reported to be between 1 to 3 mm/yr which is marginally greater than the global average (Dyurgerov and Meier, 2000; Nerem and Mitchum, 2001; Antonov et al., 2002; Arendt et al., 2002; Rignot et al., 2003; Woodworth et al., 2004). A rate of sea-level rise of 3.1 mm/yr has been reported over the past decade compared to 1.7 to 2.4 mm/yr over the 20th century as a whole (Arendt et al., 2002; Rignot et al., 2003), which suggests that the rate of sea-level rise has accelerated relative to the long-term average.

10.3.2 Socio-economics

In the SRES framework narrative storylines 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 (GHG) and sulphur emissions, and atmospheric composition (Nakićenović and Swart, 2000). In Asia, GHG emissions were quantified reflecting socio-economic development such as energy use, land-use changes, industrial production processes, and so on. The population growth projections for Asia range between 1.54 billion people in 2050 and 4.5 billion people in 2100 (Nakićenović and Swart, 2000). The economic growth is estimated to range between 4.2-fold and 3.6-fold of the current gross domestic product (GDP), respectively.

10.4 Key future impacts and vulnerabilities

Key future climate change impacts and vulnerabilities for Asia are summarised in Figure 10.4. A detailed discussion of these impacts and vulnerabilities are presented in the sections below.

10.4.1 Agriculture and food security

10.4.1.1 Production

Results of recent studies suggest that substantial decreases in cereal production potential in Asia could be likely by the end of this century as a consequence of climate change. However, regional differences in the response of wheat, maize and rice yields to projected climate change could likely be significant (Parry et al., 1999; Rosenzweig et al., 2001). Results of crop yield projection using HadCM2 indicate that crop yields could likely increase up to 20% in East and South-East Asia while it could decrease up to 30% in Central and South Asia even if the direct positive physiological effects of CO_2 are taken into account. As a consequence of the combined influence of fertilisation effect and the accompanying thermal stress and

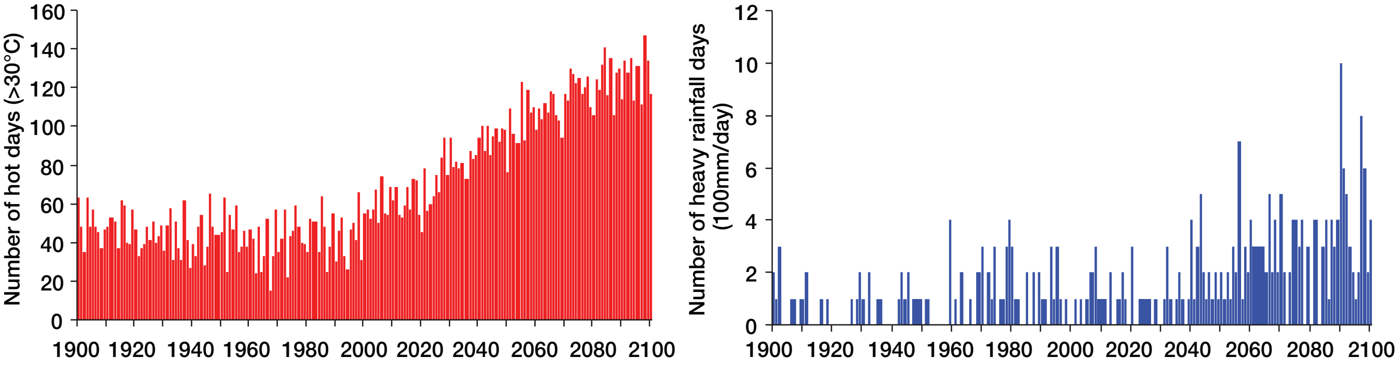


Figure 10.2. *Projected number of hot days (>30°C) and days of heavy rainfall (>100 mm/day) by the high resolution general circulation model (Hasumi and Emori, 2004).*

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 to 2039				2040 to 2069				2070 to 2099			
		Temperature °C		Precipitation %		Temperature °C		Precipitation %		Temperature °C		Precipitation %	
		A1FI	B1	A1FI	B1	A1FI	B1	A1FI	B1	A1FI	B1	A1FI	B1
North	DJF	2.94	2.69	16	14	6.65	4.25	35	22	10.45	5.99	59	29
Asia	MAM	1.69	2.02	10	10	4.96	3.54	25	19	8.32	4.69	43	25
(50.0N-67.5N;	JJA	1.69	1.88	4	6	4.20	3.13	9	8	6.94	4.00	15	10
40.0E-170.0W)	SON	2.24	2.15	7	7	5.30	3.68	14	11	8.29	4.98	25	15
Central	DJF	1.82	1.52	5	1	3.93	2.60	8	4	6.22	3.44	10	6
Asia	MAM	1.53	1.52	3	-2	3.71	2.58	0	-2	6.24	3.42	-11	-10
(30N-50N;	JJA	1.86	1.89	1	-5	4.42	3.12	-7	-4	7.50	4.10	-13	-7
40E-75E)	SON	1.72	1.54	4	0	3.96	2.74	3	0	6.44	3.72	1	0
West	DJF	1.26	1.06	-3	-4	3.1	2.0	-3	-5	5.1	2.8	-11	-4
Asia	MAM	1.29	1.24	-2	-8	3.2	2.2	-8	-9	5.6	3.0	-25	-11
(12N-42N;	JJA	1.55	1.53	13	5	3.7	2.5	13	20	6.3	2.7	32	13
27E-63E)	SON	1.48	1.35	18	13	3.6	2.2	27	29	5.7	3.2	52	25
Tibetan	DJF	2.05	1.60	14	10	4.44	2.97	21	14	7.62	4.09	31	18
Plateau	MAM	2.00	1.71	7	6	4.42	2.92	15	10	7.35	3.95	19	14
(30N-50N;	JJA	1.74	1.72	4	4	3.74	2.92	6	8	7.20	3.94	9	7
75E-100E)	SON	1.58	1.49	6	6	3.93	2.74	7	5	6.77	3.73	12	7
East	DJF	1.82	1.50	6	5	4.18	2.81	13	10	6.95	3.88	21	15
Asia	MAM	1.61	1.50	2	2	3.81	2.67	9	7	6.41	3.69	15	10
(20N-50N;	JJA	1.35	1.31	2	3	3.18	2.43	8	5	5.48	3.00	14	8
100E-150E)	SON	1.31	1.24	0	1	3.16	2.24	4	2	5.51	3.04	11	4
South	DJF	1.17	1.11	-3	4	3.16	1.97	0	0	5.44	2.93	-16	-6
Asia	MAM	1.18	1.07	7	8	2.97	1.81	26	24	5.22	2.71	31	20
(5N-30N;	JJA	0.54	0.55	5	7	1.71	0.88	13	11	3.14	1.56	26	15
65E-100E)	SON	0.78	0.83	1	3	2.41	1.49	8	6	4.19	2.17	26	10
South-East	DJF	0.86	0.72	-1	1	2.25	1.32	2	4	3.92	2.02	6	4
Asia	MAM	0.92	0.80	0	0	2.32	1.34	3	3	3.83	2.04	12	5
(10S-20N;	JJA	0.83	0.74	-1	0	2.13	1.30	0	1	3.61	1.87	7	1
100E-150E)	SON	0.85	0.75	-2	0	1.32	1.32	-1	1	3.72	1.90	7	2

water scarcity (in some regions) under the projected climate change scenarios, rice production in Asia could decline by 3.8% by the end of the 21st century (Murdiyarso, 2000). In Bangladesh, production of rice and wheat might drop by 8% and 32%, respectively, by the year 2050 (Faisal and Parveen, 2004). For the warming projections under A1FI emission scenarios (see Table 10.5), decreases in crop yields by 2.5 to 10% in 2020s and 5 to 30% in 2050s have been projected in parts of Asia (Parry et al., 2004). Doubled CO_2 climates could decrease rice yields, even in irrigated lowlands, in many prefectures in central and southern Japan by 0 to 40% (Nakagawa et al., 2003) through the occurrence of heat-induced floret sterility (Matsui and Omasa, 2002). 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).

Crop simulation modelling studies based on future climate change scenarios indicate that substantial loses are likely in rain-fed wheat in South and South-East Asia (Fischer et al., 2002). For example, a 0.5°C rise in winter temperature would reduce wheat yield by 0.45 tonnes per hectare in India (Lal et al., 1998; Kalra et al., 2003). More recent studies suggest a 2 to 5% decrease in yield potential of wheat and maize for a temperature rise of 0.5 to 1.5°C in India (Aggarwal, 2003). Studies also suggest that a 2°C increase in mean air temperature could decrease rain-fed rice yield by 5 to 12% in China (Lin et al., 2004). In South Asia, the drop in yields of non-irrigated wheat and rice will be significant for a temperature increase of beyond 2.5°C incurring a loss in farm-level net revenue of between 9% and 25% (Lal, 2007). 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

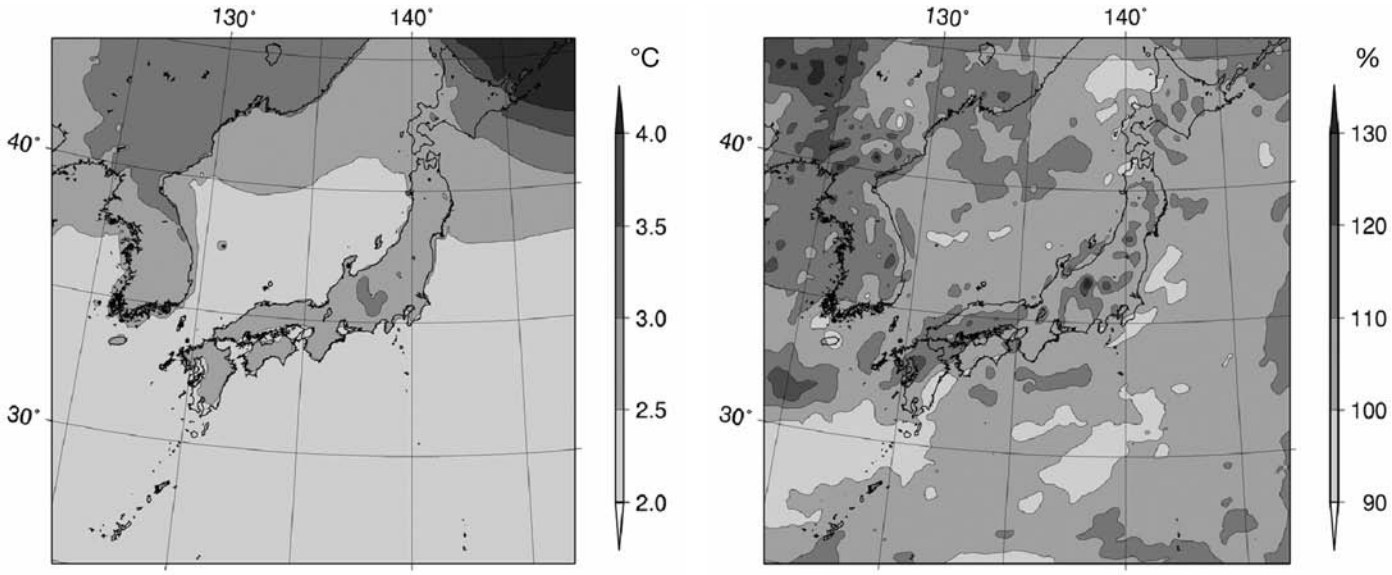
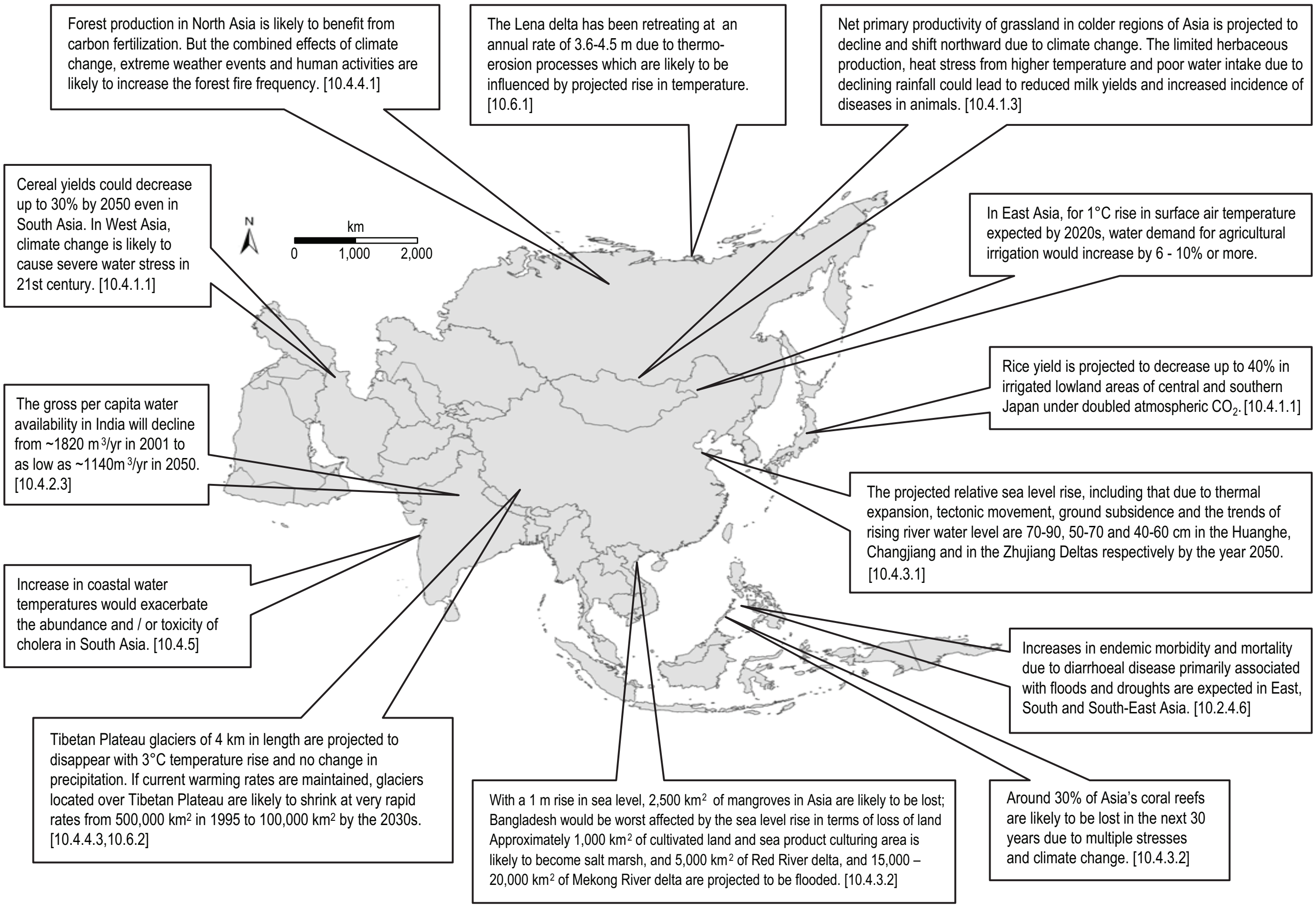


Figure 10.3. *Projected change in annual mean surface air temperature (°C) and rainfall (%) during 2081 to 2100 period compared to 1981 to 2000 period simulated by a high resolution regional climate model (left: annual temperature, right: annual precipitation, Japan Meteorological Agency, 2005; Kurihara et al., 2005).*

change scenario (Lal, 2007). 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).



Forest production in North Asia is likely to benefit from carbon fertilization. But the combined effects of climate change, extreme weather events and human activities are likely to increase the forest fire frequency. [10.4.4.1]

The Lena delta has been retreating at an annual rate of 3.6-4.5 m due to thermo-erosion processes which are likely to be influenced by projected rise in temperature. [10.6.1]

Net primary productivity of grassland in colder regions of Asia is projected to decline and shift northward due to climate change. The limited herbaceous production, heat stress from higher temperature and poor water intake due to declining rainfall could lead to reduced milk yields and increased incidence of diseases in animals. [10.4.1.3]

Cereal yields could decrease up to 30% by 2050 even in South Asia. In West Asia, climate change is likely to cause severe water stress in 21st century. [10.4.1.1]

In East Asia, for 1°C rise in surface air temperature expected by 2020s, water demand for agricultural irrigation would increase by 6 - 10% or more.

Rice yield is projected to decrease up to 40% in irrigated lowland areas of central and southern Japan under doubled atmospheric CO_2. [10.4.1.1]

The gross per capita water availability in India will decline from ~1820 m^3/yr in 2001 to as low as ~1140m^3/yr in 2050. [10.4.2.3]

The projected relative sea level rise, including that due to thermal expansion, tectonic movement, ground subsidence and the trends of rising river water level are 70-90, 50-70 and 40-60 cm in the Huanghe, Changjiang and in the Zhujiang Deltas respectively by the year 2050. [10.4.3.1]

Increase in coastal water temperatures would exacerbate the abundance and / or toxicity of cholera in South Asia. [10.4.5]

Increases in endemic morbidity and mortality due to diarrhoeal disease primarily associated with floods and droughts are expected in East, South and South-East Asia. [10.2.4.6]

Tibetan Plateau glaciers of 4 km in length are projected to disappear with 3°C temperature rise and no change in precipitation. If current warming rates are maintained, glaciers located over Tibetan Plateau are likely to shrink at very rapid rates from 500,000 km^2 in 1995 to 100,000 km^2 by the 2030s. [10.4.4.3,10.6.2]

With a 1 m rise in sea level, 2,500 km^2 of mangroves in Asia are likely to be lost; Bangladesh would be worst affected by the sea level rise in terms of loss of land Approximately 1,000 km^2 of cultivated land and sea product culturing area is likely to become salt marsh, and 5,000 km^2 of Red River delta, and 15,000 – 20,000 km^2 of Mekong River delta are projected to be flooded. [10.4.3.2]

Around 30% of Asia's coral reefs are likely to be lost in the next 30 years due to multiple stresses and climate change. [10.4.3.2]

Figure 10.4. *Hotspots of key future climate impacts and vulnerabilities in Asia.*

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 (Tserendash et al., 2005). Studies suggest that by the middle of this century in northern China, tri-planting boundary will likely shift by 500 km from Changjiang valley to Huanghe 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 could marginally increase in the Russian Federation and in East Asia (Fischer et al., 2002).

More than 28 Mha in South and East Asia require a substantial increase in irrigation for sustained productivity (FAO, 2003). Agricultural irrigation demand in arid and semi-arid regions of Asia is estimated to increase by at least 10% for an increase in temperature of 1°C (Fischer et al., 2002; Liu, 2002). The rain-fed crops in the plains of North and North-East China could 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).

As land for agriculture becomes limited, the need for more food in South Asia could likely be met by increasing yields per unit of land, water, energy and time, such as through precision farming. Enhanced variability in hydrological characteristics will likely continue to affect grain supplies and food security in many nations of Asia. Intensification of agriculture will be the most likely means to meet the food requirements of Asia, which is likely to be invariably affected by projected climate change.

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 (Sukumar et al., 2003; Christensen et al., 2004; Tserendash et al., 2005). The limited herbaceous production, heat stress from higher temperature, and limited water intake due to a decrease in rainfall could cause reduced milk yields in animals and an increased incidence of some diseases.

The Asia-Pacific region is the world's largest producer of fish, from both aquaculture and capture fishery sectors. Recent studies suggest a reduction of primary production in the tropical oceans because of changes in oceanic circulation in a warmer atmosphere. The tuna catch of East Asia and South-East Asia is nearly one-fourth 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). Marine fishery in China is facing threats from over fishing, pollution, red tide, and other climatic and environmental pressures. The migration route and migration pattern and, hence, regional catch of principal marine fishery species, such as ribbon fish, small and large yellow croakers, could be greatly affected by global climate change (Su and Tang, 2002; Zhang and Guo, 2004). Increased frequency of El Niño events could likely lead to measurable declines in fish larvae abundance in coastal waters of South and South-East Asia. These phenomena are expected to contribute to a general decline in fishery production in the coastal waters of East, South and South-East Asia. 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 could increase productivity of fish-prey and provide more extensive habitats. In contrast, the northern shrimp will likely decrease with rise in sea-surface temperatures (ACIA, 2005).

The impact of climate change on Asian fishery depends on the complicated food chains in the surrounding oceans, which are likely to be disturbed by the climate change. Fisheries at higher elevations are likely to be adversely affected by lower availability of oxygen, due to a rise in surface air temperatures. In the plains, the timing and amount of precipitation could also affect the migration of fish species from the river to the floodplains for spawning, dispersal and growth (FAO, 2003). Future changes in ocean currents, sea level, sea-water temperature, salinity, wind speed and direction, strength of upwelling, the mixing layer thickness and predator response to climate change have the potential to substantially alter fish breeding habitats and food supply for fish and ultimately the abundance of fish populations in Asian waters (IPCC, 2001).

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. For example, India’s surplus grain in past few years has been used to provide food aid to drought-affected Cambodia (Fischer et al., 2002). However, increasing urbanisation and population in Asia will likely 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). Localised increases in food prices could be frequently observed. Subsistence producers growing crops, such as sorghum, millet, 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, is likely to remain very high in several developing countries with an additional 49 million, 132 million and 266 million people of Asia projected under A2 scenario without carbon fertilisation that could be at risk of hunger by 2020, 2050 and 2080, respectively (Parry et al., 2004). In terms of percent increase in risk hunger, it is projected under A2 scenario without CO_2 fertilisation that an increase of 7 to 14% by 2020s, 14 to 40% by 2050s and 14 to 137% by 2080s are likely (Parry et al., 2004).

Some recent studies (PAGASA, 2001; Sukumar et al., 2003; Batima et al., 2005b) confirm TAR findings that grasslands, livestock and water resources in marginal areas of Central Asia and South-East Asia are likely to be vulnerable to climate change. Food insecurity and loss of livelihood are likely to be 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 likely improve land conditions and reduce pressures arising from climate change.

10.4.1.5 Pests and diseases

Some studies (Rosenzweig et al., 2001; FAO, 2004c) agree that higher temperatures and longer growing seasons could result in increased pest populations in temperate regions of Asia. CO_2 enrichment and changes in temperature may also affect ecology, the evolution of weed species over time and the competitiveness of C_3 v. C_4 weed species (Ziska, 2003). Warmer winter temperatures would reduce winter kill, favouring the increase of insect populations. 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 warmer winter temperatures, and by making the crop more vulnerable.

Climate change, as well as changing pest and disease patterns, will likely affect how food production systems perform 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 likely 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 are also likely to be affected negatively by an increase in food prices that may result from declining food production.

10.4.2 Hydrology and water resources

10.4.2.1 Water availability and demand

The impacts of climate change on water resources in Asia will be positive in some areas and negative in others. Changes in seasonality and amount of water flows from river systems are likely to occur due to climate change. In some parts of Russia, climate change could significantly alter the variability of river runoff such that extremely low runoff events may occur much more frequently in the crop growing regions of the south west (Peterson et al., 2002). Changes in runoff of river basins could have a significant effect on the power output of hydropower generating countries like Tajikistan, which is the third-highest producer in the world (World Bank, 2002). Likewise, surface water availability from major rivers like the Euphrates and Tigris may also be affected by alteration of riverflows. In Lebanon the annual net usable water resources will likely decrease by 15% in response to a general circulation model (GCM) estimated average rise in temperature of 1.2°C under doubled CO_2 climate, while the flows in rivers are likely to increase in winter and decrease in spring (Bou-Zeid and El-Fadel, 2002) which could negatively affect existing uses of river waters. In North China, irrigation from surface and groundwater sources will meet only 70% of the water requirement for agricultural production, due to the effects of climate change and increasing demand (Liu et al., 2001; Qin, 2002). The maximum monthly flow of the Mekong is estimated to increase by 35 to 41% in the basin and by 16 to 19% in the delta, with lower value estimated for years 2010 to 38 and higher value for years 2070 to 99, compared with 1961 to 90 levels. In contrast, the minimum monthly flows are estimated to decline by 17 to 24% in the basin and 26 to 29% in the delta (see Chapter 5, Box 5.3; Hoanh et al., 2004) suggesting that there could be increased flooding risks during wet season and an increased possibility of water shortage in dry season. Flooding could increase the habitat of brackish water fisheries but could also seriously affect the aquaculture industry and infrastructure, particularly in heavily-populated megadeltas. Decrease in dry season flows may reduce recruitment of some species.

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). Climate change-related melting of glaciers could seriously affect half a billion people in the Himalaya-Hindu-Kush region and a quarter of a billion people in China who depend on glacial melt for their water supplies (Stern, 2007). As glaciers melt, river runoff will initially increase in winter or spring but eventually will decrease as a result of loss of ice resources. Consequences for downstream agriculture, which relies on this water for irrigation, will be likely unfavourable in most countries of South Asia. The thawing volume and speed of snow cover in spring is projected to accelerate in North-West China and Western Mongolia and the thawing time could advance, which will increase some water sources and may lead to floods in spring, but significant shortages in wintertime water availability for livestock are projected by the end of this century (Batima et al., 2004, 2005b).

10.4.2.2 Water quality

Over-exploitation of groundwater in many countries of Asia has resulted in a drop in its level, leading to ingress of sea water in coastal areas making the sub-surface 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 increases in sea level as a direct impact of global warming (Han et al., 1999). Rising sea level by 0.4 to 1.0 m can induce salt-water intrusion 1 to 3 km further 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 salt-water intrusion in the estuary (Xu, 2003; Thanh et al., 2004; Huang et al., 2005) and thus deteriorate surface and groundwater quality.

10.4.2.3 Implications of droughts and floods

Global warming would cause an abrupt rise of water quantity as a result of snow or glacier melting that, in turn, would lead to floods. The floods quite often are caused by rise of river water level due to blockage of channels by drifting ice, as happened in Central Siberia, Lensk, or enormous precipitation from destructive shower cyclones, as it was in the North Asia Pacific coast, Vladivostok (Izrael et al., 2002a). A projected increase in surface air temperature in North-West China will result in a 27% decline in glacier area (equivalent to the ice volume of 16,184 km^3), a 10 to 15% decline in frozen soil area, an increase in flood and debris flow, and more severe water shortages (Qin, 2002). The duration of seasonal snow cover in alpine areas, namely the Tibetan Plateau, Xinjiang and Inner Mongolia of China, will shorten and snow cover will thaw out in advance of the spring season, leading to a decline in volume and resulting in severe spring droughts. Between 20 to 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 socio-economic development on water resources is likely to grow. Higashi et al. (2006) project that future flood risk in Tokyo, Japan between 2050 to 2300 under SRES A1B is likely to be 1.1 to 1.2 times higher than the present condition.

The gross per capita water availability in India will decline from about 1,820 m^3/yr in 2001 to as low as about 1,140 m^3/yr in 2050 (Gupta and Deshpande, 2004). India will reach a state of water stress before 2025 when the availability falls below 1000 m^3 per capita (CWC, 2001). The projected decrease in the winter precipitation over the Indian subcontinent would reduce the total seasonal precipitation during December, January and February implying lesser storage and 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 rainwater 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 South-East Asia in the foreseeable future as the number of people living under severe water stress is likely to increase substantially in absolute terms. It is estimated that under the full range of SRES scenarios, 120 million to 1.2 billion, and 185 to 981 million people will experience increased water stress by the 2020s, and the 2050s, respectively (Arnell, 2004). The decline in annual flow of the Red River by 13 to 19% and that of Mekong River by 16 to 24% by the end of 21st century will contribute in increasing water stress (ADB, 1994).

10.4.3 Coastal and low lying areas

10.4.3.1 Coastal erosion and inundation of coastal lowland

Average global sea-level rise over the second half of the 20th century was 1.8 ± 0.3 mm/yr, and sea-level rise of the order of 2 to 3 mm/yr is considered likely during the early 21st century as a consequence of global warming (Woodroffe et al., 2006). However, the sea-level rise in Asia is geographically variable and an additional half a metre of sea-level rise is projected for the Arctic during this century (ACIA, 2005). The rising rates of sea level vary considerably from 1.5 to 4.4 mm/yr 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 could be 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 to 60 cm, 50 to 70 cm and 70 to 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 north-western 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, 2005).

In Asia, erosion is the main process that will occur to land as sea level continues to rise. As a consequence, coast-protection structures built by humans will usually 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 45 m of landward erosion. Climate change and sea-level rise will tend to worsen the currently eroding coasts (Huang and Xie, 2000). In Boreal Asia, coastal erosion will be enhanced as rising sea level and declining sea ice allow higher wave and storm surge to hit the shore (ACIA, 2005). The coastal recession can add up to 500 to 600 m in 100 years, with a rate of between 4 to 6 m/yr. The coastal recession by thermal abrasion is expected to accelerate by 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, decreasing sediment flux is generally a main cause of coastal erosion. Available evidence suggests a tendency of river sediment to further decline that will tend to worsen coastal erosion in Asia (Liu et al., 2001).

Projected sea-level rise could flood the residence of millions of people living in the low lying areas of South, South-East and East Asia such as in Vietnam, Bangladesh, India and China (Wassmann et al., 2004; Stern, 2007). 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 projected to increase the annual number of people flooded in coastal populations 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 South-East Asia, specifically from Thailand to Vietnam including Indonesia and the Philippines (Wassmann et al., 2004). The potential impacts of one metre sea-level rise include inundation of 5,763 km^2 and 2,339 km^2 in India and in some big cities of Japan, respectively (TERI, 1996; Mimura and Yokoki, 2004). For one metre 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). In China, a 30 cm sea-level rise would inundate 81,348 km^2 of coastal lowland (Du and Zhang, 2000).

The coastal lowlands below the elevation of 1,000-year storm surge are widely distributed in Bangladesh, China, Japan, Vietnam and Thailand, where millions of people live (Nicholls, 2004). In Japan, an area of 861 km^2 of coastal lowland is located below high water level mainly in large cities like Tokyo, Osaka and Nagoya. A one metre rise in sea level could put up to 4.1

million people at risk (Mimura and Yokoki, 2004). Using a coarse digital terrain model and global population distribution data, it is estimated that more than 1 million people will be directly affected by sea-level rise in 2050 in each of the Ganges-Brahmaputra-Meghna delta in Bangladesh, the Mekong delta in Vietnam and the Nile delta in Egypt (see Chapter 6, Box 6.3; Ericson et al., 2005). Damages in flooded areas are largely dependent on the coastal protection level. It can be much less in highly protected coasts like in Japan but can be very high such as in coastal areas of South Asia where the protection level is low. A 30 cm rise in sea level will increase coastal flooding areas by five or six times in both the 'with' and 'without protection' scenarios in the Changjiang and Zhujiang deltas. Similarly, the flooding areas in the Huanghe delta for a 100 cm rise in sea level are almost the same under the 'without protection' and 'existing protection' scenarios. These two cases indicate that the current protection level is insufficient to protect the coasts from high sea-level rise (Du and Zhang, 2000; Li et al., 2004a). Further climate warming may lead to an increase in tropical cyclone destructive potential, and with an increasing coastal population substantial increase in hurricane-related losses in the 21st century is likely (Emanuel, 2005).

In summary, 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.

10.4.3.2 Deltas, estuaries, wetland and other coastal ecosystems

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 groundwater for irrigation and reservoir construction upstream. In the Tibetan Plateau and adjoining region, sediment starvation is generally the main cause of shrinking of deltas. Annual mean sediment discharge in the Huanghe delta during the 1990s was only 34% of that observed during the 1950s and 1970s. The Changjiang sediment discharge will also be reduced by 50% on average after construction of the Three-Gorges Dam (Li et al., 2004b). Saltwater intrusion in estuaries due to decreasing river runoff can be pushed 10 to 20 km further inland by the rising sea level (Shen et al., 2003; Yin et al., 2003; Thanh et al., 2004).

Many megacities in Asia are located on deltas formed during sea-level change in the Holocene period (Hara et al., 2005). These Asian megacities with large populations and intensified socio-economic activities are subject to threats of climate change, sea-level rise and extreme climate event. For a 1 m rise in sea level, half a million square hectares of Red River delta and from 15,000 to 20,000 km^2 of Mekong River delta is projected to be flooded. In addition, 2,500 km^2 of mangrove will be completely lost, while approximately 1,000 km^2 of cultivated farm land and sea product culturing area will become salt marshes (Tran et al., 2005).

Rise in water temperatures and eutrophication in the Zhujiang and Changjiang estuaries have led to the formation of the bottom oxygen-deficient horizon and an increase in the frequency and intensity of red tides (Hu et al., 2001). Projected increases in the frequency and intensity of extreme weather events will exert adverse impacts on aquatic ecosystems, and existing habitats will be redistributed, affecting estuarine flora distribution (Short and Neckles, 1999; Simas et al., 2001; Lu, 2003; Paerl et al., 2003).

Recent risk analysis of coral reefs suggests that between 24% and 30% of the reefs in Asia are projected to be lost during the next 2 to 10 years and 10 to 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 Asia may be as high as 88% (59% for global) in the next 30 years under IS92a emission scenario (IPCC, 1992; Sheppard, 2003; Wilkinson, 2004). If conservation measures receive increasing attention, large areas of the reefs could recover from the direct and indirect damage within the next 10 years. However, if abnormally high sea-surface temperatures (SST) continue to cause major bleaching events (see Chapter 6, Section 6.2.5, Box 6.1), and reduce the capacity of reefs to calcify due to CO_2 increase, most human efforts will be futile (Kleypas et al., 1999; Wilkinson, 2002).

A new study suggests that coral reefs, which have been severely affected by abnormally high SST in recent years, contain some coral species and their reef-associated micro-algal symbionts that show far greater tolerance to higher SST than others. Bleaching thresholds may be more realistically visualised as a broad spectrum of responses, rather than a single bleaching threshold for all coral species (Hughes et al., 2003; Baker et al., 2004). This corals' adaptive response to climate change may protect devastated reefs from extinction or significantly prolong the extinction of surviving corals beyond previous assumption.

Net growth rates of coral reef, which can reach up to 8 to 10 mm/year, may exceed the projected rates of future sea-level rise in the South China Sea, so that coral reefs could not be at risk due merely to sea-level rise. Water depth increased by sea-level rise would lead to storminess and destruction of coral reefs (Knowlton, 2001; Wang, 2005).

10.4.4 Natural ecosystems and biodiversity

10.4.4.1 Structure, production and function of forests

Up to 50% of the Asia's total biodiversity is at risk due to climate change. Boreal forests in North Asia would move further north. A projected large increase in taiga is likely to displace tundra, while the northward movement of the tundra will in turn decrease polar deserts (see Chapter 15, Section 15.2.2, Figure 15.3; Callaghan et al., 2005; Juday et al., 2005). Large populations of many other species could also be extirpated as a result of the synergistic effects of climate change and habitat fragmentation (Ishigami et al., 2003, 2005). Projections under doubled-CO_2 climate using two GCMs show that 105 to 1,522 plant species and 5 to 77 vertebrates in China and 133 to 2,835

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

Region	Coral reef area (km²)	Destroyed reefs (%)	Reefs recovered since 1998 (%)	Reefs at critical stage (%)	Reefs at threatened stage (%)	Reefs at low or no threat level (%)
Red Sea	17,640	4	2	2	10	84
The Gulfs	3,800	65	2	15	15	5
South Asia	19,210	45	13	10	25	20
S-E Asia	91,700	38	8	28	29	5
E & N Asia	5,400	14	3	23	12	51
Total	137,750	34.4	7.6	21.6	25.0	19.0
Asia	(48.4%)					

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.

plants and 10 to 213 vertebrates in Indo-Burma could become extinct (Malcolm et al., 2006).

As a consequence of climate change, no significant change in spatial patterns of productivity of the forest ecosystems in North-East China is projected (Liu et al., 1998). The areal coverage of broad-leaved Korean pine forests is projected to decrease by 20 to 35% with a significant northward shift (Wu, 2003). About 90% of the suitable habitat for a dominant forest species, beech tree (*Fagus crenata*), in Japan could disappear by the end of this century (Matsui et al., 2004a, b). The impact of elevated atmospheric CO_2 on plant biomass production is influenced by the availability of soil nitrogen and deposition of atmospheric nitrogen (Oren et al., 2001; Hajima et al., 2005; Kitao et al., 2005; Reich et al., 2006). The overall impact of climate change on the forest ecosystems of Pakistan could be negative (Siddiqui et al., 1999).

The observations in the past 20 years show that the increasing intensity and spread of forest fires in North and South-East Asia were largely related to rises in temperature and declines in precipitation in combination with increasing intensity of land uses (see Section 10.2.4.4). Whether this trend will persist in the future or not is difficult to ascertain in view of the limited literature on how the frequency and severity of forest and brush fires will likely respond to expected increase in temperature and precipitation in North and South-East Asia (see Section 10.3.1). The uncertainty lies on whether the expected increase in temperature would be enough to trigger more frequent and severe fires despite the projected increase in precipitation. One study on the impacts of climate change on fires show that for an average temperature increase of 1°C, the duration of wild fire season in North Asia could increase by 30% (Vorobyov, 2004), which could have varying adverse and beneficial impacts on biodiversity, forest structure and composition, outbreaks of pest and diseases, wildlife habitat quality and other key forest ecosystem functions.

10.4.4.2 Grasslands, rangelands and endangered species

The natural grassland coverage and the grass yield in Asia, in general, are projected to decline with a rise in temperature and higher evaporation (Lu and Lu, 2003). Large decreases in the natural capital of grasslands and savannas are likely in South Asia as a consequence of climate change. A rise in surface air temperature and decline in precipitation is estimated to reduce pasture productivity in the Mongolian steppe by about 10 to 30%, except in high mountains and in Gobi where a marginal decrease in pasture productivity is projected by the end of this century (Tserendash et al., 2005). Traditional land-use systems should provide conditions that would promote greater rangeland resilience and 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 a shift of the boundary of the farming-pastoral transition region to the south in North-East 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 (Li and Zhou, 2001; Qiu et al., 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 Permafrost

The permafrost thawing will continue over vast territories of North Asia under the projected climate change scenarios (Izrael et al., 2002b). The transient climate model simulations (Pavlov and Ananjeva-Malkova, 2005; FNCRF, 2006) show that the perennially frozen rocks and soils (eastern part of the permafrost terrain) and soils (western part of the terrain) may be completely degraded within the present southern regions of North Asia (see Figure 10.5). In northern regions, mean annual temperature of frozen soil and rocks and the depth of seasonal thawing will increase in 2020 by as much as 4°C for the depth of 0.8 m and by at most 2.2°C for the depth of 1.6 m (FNCRF, 2006; Izrael et al., 2006). The change in the rock and soil temperatures will result in a change in the strength characteristics, bearing capacity, and compressibility of the frozen rocks and soils, 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).

Permafrost degradation will lead to significant ground surface subsidence and pounding (Osterkamp et al., 2000; Jorgenson et al., 2001). Permafrost thawing on well-drained portions of slopes and highlands in Russia and Mongolia will improve the drainage conditions and lead to a decrease in the groundwater content (Hinzman et al., 2003; Batima et al., 2005b). On the Tibetan Plateau, in general, the permafrost zone is expected to decrease in size, move upward and face degradation by the end of this century (Wu et al., 2001). For a rise in surface temperature of 3°C and no change in precipitation, most Tibetan Plateau glaciers shorter than 4 km in length are projected to disappear and the glacier areas in the Changjiang Rivers will likely decrease by more than 60% (Shen et al., 2002).

Figure 10.5. *The projected shift of permafrost boundary in North Asia due to climate change by 2100 (FNCRF, 2006).*

10.4.5 Human health

Climate change poses substantial risks to human health in Asia. Global burden (mortality and morbidity) of climate-change attributable diarrhoea and malnutrition are already the largest in South-East Asian countries including Bangladesh, Bhutan, India, Maldives, Myanmar and Nepal in 2000, and the relative risks for these conditions for 2030 is expected to be also the largest (McMichael et al., 2004), although in some areas, such as southern states in India, there will be a reduction in the transmission season by 2080 (Mitra et al., 2004). An empirical model projected that the population at risk of dengue fever (the estimated risk of dengue transmission is greater than 50%) will be larger in India and China (Hales et al., 2002). Also in India and China, the excess mortality due to heat stress is projected to be very high (Takahashi et al., 2007), although this projection did not take into account possible adaptation and population change. There is already evidence of widespread damage to human health by urban air quality and enhanced climate variability in Asia. Throughout newly industrialised areas in Asia, such as Chongqing, China, and Jakarta, Indonesia, air quality has deteriorated significantly and will likely contribute to widespread heat stress and smog induced cardiovascular and respiratory illnesses in the region (Patz et al., 2000). Also, the number of patients of Japanese cedar pollen disease is likely to increase when the summer temperature rises (Takahashi and Kawashima, 1999; Teranishi et al., 2000).

The negative influence of temperature anomalies on public health has been established in Russia (Izmerov et al., 2004) and in the semi-arid city, Beirut (El-Zein et al., 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., 1995). Natural habitats of vector-borne diseases are reported to be expanding (Izmerov et al., 2004). Prevalence of malaria and tick-borne encephalitis has also increased over time in Russia (Yasukevich and Semenov, 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 viral diseases (Kovats et al., 2003). *Oncomelania* is strongly influenced by climate and the infection rate of schistosomiasis is the highest in the temperature range of 24°C to 27°C. 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. Serious problems are connected with the impact of air pollution due to Siberian forest fires on human health (Rachmanin et al., 2004).

Warmer sea-surface temperatures along coastlines of South and South-East 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. Precipitation increase and frequent floods, and sea-level rise in the future will degrade 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, assessment of climate change impacts on nutritional situation, drinking water supply, water salinity and ecosystem damage will be necessary. The risk factor of climate-related diseases will depend on improved environmental sanitation, the hygienic practice and medical treatment facilities.

10.4.6 Human dimensions

Study of social vulnerability provides a complementary approach to the study of climate impacts based on model projections and biophysical simulations. Adger et al. (2001)

illustrate the approach through theoretical discussion and case studies based in Vietnam. The following sections detail specific examples of the human dimension of general relevance within Asia.

10.4.6.1 Population growth

As of mid-2000, over 3.6 billion people, roughly three-fifths of the total population of the globe, resided in Asia. Seven of the world's 10 most populous countries - China, India, Indonesia, Russia, Pakistan, Bangladesh and Japan - are located within Asia (ADB, 2002). The majority of the region's population growth is forecast to come from South Asia, which expects to add 570 million people in India, 200 million in Pakistan and 130 million in Bangladesh over the next 50 years (UN-DESA-PD, 2002). Population growth, particularly in countries with already high population densities, is inextricably associated with the increasing pressure on the natural resources and the environment as the demands for goods and services expand. Some of the key impacts of increasing population include those linked with the intensification of use of natural forests including mangroves, agriculture, industrialisation and urbanisation. 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 industrialisation and urbanisation in pursuit of economic development (Zeqiang et al., 2001).

In the developing regions, the remaining natural flood plains are disappearing at an accelerating rate, primarily as a result of changes in land use and hydrological cycle, particularly changes in streamflows due to climatic and human-related factors. 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 South-East Asia.

In some parts of South-East 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 changes in natural forests. In the Philippines, forest degradation has been attributed partly to upland farming (Pulhin et al., 2006).

10.4.6.2 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.

Demands for biological resources caused by population and increased consumption have grown with increasing economy and fast development all over Asia in recent years. Rates of both total forest loss and forest degradation are higher 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/yr. In many developing countries of Asia, small scale fuel wood collection and industrial logging for exports of timber and conversion of forests into estate crop plantation (i.e., oil palm) and mining are also responsible for deforestation. It is likely that climate change would aggravate the adverse impacts of forest cover loss.

10.4.6.3 Climate extremes and migration

In Asia, migration accounts for 64% of urban growth (Pelling, 2003). Total population, international migration and refugees in Asia and the Pacific region are currently 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 displacement of people and changes in occupancy and migration patterns (Barnett, 2003).

Climate-related disruptions of human populations and consequent migrations can be expected over the 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 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 socio-economic 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. Concerns for the environment as well as socio-economic considerations may infringe upon the current agricultural resource base and prevent land and water resources from being developed for agriculture (Tao et al., 2003b). 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 (Wang et al., 2006).

10.4.6.4 Urban development, infrastructure linkages, industry and energy

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 (Kalnay and Cai, 2003; Patz et al., 2005). Existing stresses in urban areas include crime, traffic congestion, compromised air and water quality, and disruptions due to development and deterioration of infrastructure. Climate change

Table 10.7. *A summary of projected impacts of global warming on industries and energy sectors identified in Japan.*

Changes in climate parameters	Impacts
1°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 thunder storms	Damage to information devices and facilities
1°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	Hydroelectric power generation, management and implementation of dams, cooling water management
1°C increase in cooling water temperature	0.2 to 0.4% reduction of generation of electricity in thermal power plants, 1 to 2% reduction in nuclear power plant

is likely to amplify some of these stresses (Honda et al., 2003), although much of the interactions are not yet 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 urban areas with negative implications for energy and water consumption, human health and discomfort, and local ecosystems. Vulnerabilities of urban communities in megacities of Asia to long-term impacts of projected climate change need to be assessed 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 (McMichael et al., 2003).

Nature-based tourism is one of the booming industries in Asia, especially ski resorts, beach resorts and ecotourist destinations which are likely vulnerable to climate change; yet only a few assessment studies are on hand for this review. Fukushima et al. (2002) reported a drop of more than 30% in skiers in almost all ski areas in Japan except in the northern region (Hokkaido) and high altitude regions (centre of the Main Island) in the event of a 3°C increase in air temperature. If the mean June to August temperature rises by 1°C in Japan, consumption of summer products such as air-conditioners, beer, soft drinks, clothing and electricity are projected to increase about 5% (Harasawa and Nishioka, 2003). Table 10.7 lists a summary of projected impacts of global warming on industries and energy sectors identified in Japan.

Limited studies on the impacts of climate change on the energy sector in Asia suggest that this sector will be affected by climate change. In particular, South Asia is expected to account for one-fifth of the world's total energy consumption by the end of 21st century (Parikh and Bhattacharya, 2004). An increase in the energy consumption of industry, residential and transport sectors could be significant as population, urbanisation and industrialisation rise. It is likely that climate change will influence the pattern of change in energy consumption that could have significant effects on CO_2 emission in this region.

10.4.6.5 Financial aspects

The cost of damages from floods, typhoons and other climate-related hazards will likely increase in the future. According to the European insurer Munich Re, the annual cost of climate change-related claims could reach US$300 billion annually by 2050. The Association of British Insurers 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 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 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 cost of direct damage in Asia caused by tropical cyclones has increased more than five times in the 1980s as compared with those in the 1970s and about 35 times more in the early 1990s than in 1970s (Yoshino, 1996). Flood-related damages also increased by about three times and eight times respectively in the 1990s, relative to those in the 1980s and 1970s. These trends are likely to persist in the future.

10.4.6.6 Vulnerability of the poor

Social vulnerability is the exposure of groups of people or individuals to stress as a result of the impacts of environmental change including climate change (Adger, 2000). Social vulnerability emphasises the inequitable distribution of damages and risks amongst groups of people (Wu et al., 2002) and is a result of social processes and structures that constrain access to the resources that enable people to cope with impacts (Blaikie et al., 1994). The poor, particularly in urban and urbanising cities of Asia, are highly vulnerable to climate change because of their limited access to profitable livelihood opportunities and limited access to areas that are fit for safe and healthy habitation. Consequently, the poor sector will likely be exposed to more risks from floods and other climate-related hazards in areas they are forced to stay in (Adger, 2003). This also includes the rural poor who live in the lower Mekong countries and are dependent on fisheries as their major livelihood, along with those living in coastal areas who are likely to suffer heavy losses without appropriate protection (see Table 10.10; MRC, 2003). Protection from the social forces that create inequitable exposure to risk will be as important if not more important than structural protection from natural hazards in reducing the vulnerability of the poor (Hewitt, 1997).

10.5 Adaptation: sector-specific practices, options and constraints

10.5.1 Agriculture and food security

Many studies (Parry, 2002; Ge et al., 2002; Droogers, 2004; Lin et al., 2004; Vlek et al., 2004; Wang et al., 2004a; Zalikhanov, 2004; Lal, 2007; Batima et al., 2005c) on the impacts of climate change on agriculture and possible adaptation options have been published since the TAR. More common adaptation measures that have been identified in the above-mentioned studies are summarised in Table 10.8. Generally, these measures are intended to increase adaptive capacity by modifying farming practices, improving crops and livestock through breeding and investing in new technologies and infrastructure. Specific examples include adaptation of grassland management to the actual environmental conditions as well as the practice of reasonable rotational grazing to ensure the sustainability of grassland resources (Li et al., 2002; Wang et al., 2004a; Batima et al., 2005c), improvement of irrigation systems and breeding of new rice varieties to minimise the risk of serious productivity losses caused by climate change (Ge et al., 2002), and information, education and communication programmes to enhance the level of awareness and understanding of the vulnerable groups.

Changes in management philosophy could also enhance adaptive capacity. This is illustrated by integrating fisheries and aquaculture management into coastal zone management to increase the coping ability of small communities in East Asia, South Asia and South-East Asia to sea-level rise (Troadec, 2000).

The ability of local populations to adapt their production systems to cope with climate change will vary across Asia and will be largely influenced by the way government institutions and policies mediate the supply of, and access to, food and related resources. The adaptive capacity of poor subsistence farming/herding communities is commonly low in many developing countries of Asia. One of the important and effective measures to enhance their adaptive capacity is through education and the provision of easy access to climate change-related information.

10.5.2 Hydrology and water resources

In some parts of Asia, conversion of cropland to forest (grassland), restoration and re-establishment of vegetation, improvement of the tree and herb varieties, and selection and cultivation of new drought-resistant varieties are effective measures to prevent water scarcity due to climate change. Water saving schemes for irrigation should be enforced to avert water scarcity in regions already under water stress (Wang, 2003). In North Asia, recycling and reuse of municipal wastewater (Frolov et al., 2004), increasing efficiency of water used for irrigation and other purposes (Alcamo et al., 2004), reduction of hydropower production (Kirpichnikov et al., 2004) and improved use of rivers for navigation (Golitsyn and Yu, 2002) will likely help avert water scarcity.

Table 10.8. *Adaptation measures in agriculture*.

Sectors	Adaptation measures
1°C temperature increase in June to August	Choice of crop and cultivar: • Use of more heat/drought-tolerant crop varieties in areas under water stress • Use of more disease and pest tolerant crop varieties • Use of salt-tolerant crop varieties • Introduce higher yielding, earlier maturing crop varieties in cold regions Farm management: • Altered application of nutrients/fertiliser • Altered application of insecticide/pesticide • Change planting date to effectively use the prolonged growing season and irrigation • Develop adaptive management strategy at farm level
Livestock production	• Breeding livestock for greater tolerance and productivity • 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 • Increase plant coverage per hectare • Provide local specific support in supplementary feed and veterinary service
Fishery	• Breeding fish tolerant to high water temperature • Fisheries management capabilities to cope with impacts of climate change must be developed
Development of agricultural bio-technologies	• Development and distribution of more drought, disease, pest and salt-tolerant crop varieties • Develop improved processing and conservation technologies in livestock production • Improve crossbreeds of high productivity animals
Improvement of agricultural infrastructure	• Improve pasture water supply • Improve irrigation systems and their efficiency • Improve use/store of rain and snow water • Improve information exchange system on new technologies at national as well as regional and international level • Improve sea defence and flood management • Improve access of herders, fishers and farmers to timely weather forecasts

There are many adaptation measures that could be applied in various parts of Asia to minimise the impacts of climate change on water resources and use: several of which address the existing inefficiency in the use of water. Modernisation of existing irrigation schemes and demand management aimed at optimising physical and economic efficiency in the use of water resources and recycled water in water stressed countries of Asia could be useful in many agricultural areas in Asia, particularly in arid and semi-arid countries. Public investment policies which are aimed at improving access to available water resources, integrated water management, respect for the environment and promotion of better practices for wise use of water in agriculture, including recycled waste water could potentially enhance adaptive capacity. As an adaptation measure, apart from meeting non-potable water demands, recycled water can be used for recharging groundwater 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 now in Singapore, and the installation of distribution systems, can be initially expensive compared to such water supply alternatives as imported water or groundwater, but are potentially important adaptive options in many countries of Asia. Reduction of water wastage and leakages, which in some cities like Damascus can be substantial, could be practiced to cushion the decrease in water supply due to decline in precipitation and increase in temperature. The use of market-oriented approaches to reduce wasteful water uses could also be effective in reducing effects of climate change on water resources (Ragab and Prudhomme, 2002). In rivers like the Mekong where wet season riverflows are estimated to increase and the dry season flows projected to decrease, planned water management interventions could marginally decrease wet season flows and substantially increase dry season flows (World Bank, 2004).

10.5.3 Coastal and low lying areas

The response to sea-level rise could mean protection, accommodation and retreat. As substantial socio-economic activities and populations are currently highly concentrated in the coastal zones in Asia, protection should remain a key focus area in Asia. Coastal protection constructions in Asia for 5-year to 1,000-year storm-surge elevations need to be considered. Most megacities of Asia located in coastal zones need to ensure that future constructions are done at elevated levels (Nicholls, 2004; Nishioka and Harasawa, 1998; Du and Zhang, 2000). The dike heightening and strengthening has been identified as one of the adaptation measures for coastal protection (Du and Zhang, 2000; Huang and Xie, 2000; Li et al., 2004a, b).

Integrated Coastal Zone Management (ICZM) provides an effective coastal protection strategy to maximise the benefits provided by the coastal zone and to minimise the conflicts and harmful effects of activities on social, cultural and environmental resources to promote sustainable management of coastal zones (World Bank, 2002). The ICZM concept is being embraced as a central organising concept in the management of fisheries, coral reefs, pollution, megacities and individual coastal systems in China, India, Indonesia, Japan, Korea, the Philippines, Sri Lanka, Vietnam and Kuwait. It has been successfully applied for prevention and control of marine pollution in Batangas Bay of the Philippines and Xiamen of China over the past few years (Chua, 1999; Xue et al., 2004). The ICZM concept and principle could potentially promote sustainable coastal area protection and management in other countries of Asia.

10.5.4 Natural ecosystems and biodiversity

The probability of significant adverse impacts of climate change on Asian forests is high in the next few decades (Isaev et al., 2004). Improved technologies for tree plantation development and reforestation could likely enhance adaptation especially in vulnerable areas such as the Siberian forests. Likewise improvement of protection from fires, insects and diseases could reduce vulnerability of most forests in Asia to climate change and variability.

Comprehensive intersectoral programs that combine measures to control deforestation and forest degradation with measures to increase agricultural productivity and sustainability will likely contribute more to reducing vulnerability of forests to climate change, land use change and other stress factors than independent sectoral initiatives. Other likely effective adaptation measures to reduce the impacts of climate change on forest ecosystems in Asia include extending rotation cycles, reducing damage to remaining trees, reducing logging waste, implementing soil conservation practices, and using wood in a more carbon-efficient way such that a large fraction of their carbon is conserved.

10.5.5 Human health

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 need to be identified, along with barriers to successful adaptation and the means of overcoming such barriers.

The heat watch and warning system in the USA was evaluated to be effective (Ebi et al., 2004). Also, a similar system was operated in Shanghai, China (Tan et al., 2004). Implementation of this type of heat watch and warning system and other similar monitoring systems in other parts of Asia will likely be helpful in reducing the impacts of climate change on human health.

10.5.6 Human dimensions

Rapid population growth, urbanisation and weak land-use planning and enforcement 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. Social capital has been paid attention to build adaptive capacity (Allen, 2006). For example, a community-based disaster management programme was introduced to reduce vulnerability and to strengthen people's capacity to cope with hazards by the Asian Disaster Preparedness Centre, Bangkok (Pelling, 2003).

Tourism is one of the most important industries in Asia, which is the third centre of tourism activities following Europe and North America. Sea-level rise, warming sea temperatures and extreme weather events are likely to have impacts on the regions' islands and coasts which attract considerable number of visitors from countries such as Japan and Taiwan (World Tourism Organization, 2003; Hamilton et al., 2005). Relevant adaptation measures in this case include designing and building appropriate infrastructures to protect tourists, installation and maintenance of weather prediction and hazard warning systems, especially during rainy and tropical storm seasons. Conservation of mangroves is considered as effective natural protection against storm surges, coastal erosion and strong wave actions (Mazda et al., 1997, 2006; Vermaat and Thampanya, 2006). To minimise the anticipated impact of global warming on the ski industry, development of new leisure industries more resistant to or suited to a warmer atmosphere, thus avoiding excessive reliance on the ski industry, e.g., grass-skiing, hiking, residential lodging and eco-tourism, could be helpful in compensating for the income reduction due to snow deterioration (Fukushima et al., 2002).

To minimise the risks of heat stress that are most pronounced in large cities due to the urban heat-island effect in summer (Kalnay and Cai, 2003) urban planning should consider: reducing the heat island in summer, the heat load on buildings, cooling load and high night-time temperature, and taking climate change into account in planning new buildings and setting up new regulations on buildings and urban development. Planting trees, building houses with arcades and provision for sufficient ventilation could help in reducing heat load (Shimoda, 2003). The use of reflective surfaces, control of solar radiation by vegetation and blinds, earth tubes, the formation of air paths for natural ventilation, and rooftop planting could reduce the cooling load.

10.5.7 Key constraints and measures to strengthen adaptation

Effective adaptation and adaptive capacity in Asia, particularly in developing countries, will continue to be limited by several ecological, social and economic, technical and political constraints including spatial and temporal uncertainties associated with forecasts of regional climate, low level of awareness among decision makers of the local and regional impacts of El Niño, limited national capacities in climate monitoring and forecasting, and lack of co-ordination in the formulation of responses (Glantz, 2001).

Radical climate change may cause alterations of the physical environment in an area that may limit adaptation possibilities (Nicholls and Tol, 2006). For example, migration is the only option in response to sea-level rise that inundates islands and coastal settlements (see Chapter 17, Section 17.4.2.1). Likewise, impacts of climate change may occur beyond certain thresholds in the ability of some ecosystems to adapt without dramatic changes in their functions and resilience. The inherent sensitivity of some ecosystems, habitats and even species with extremely narrow ranges of biogeographic adaptability will also limit the options and effectiveness of adaptation.

Poverty is identified as the largest barrier to developing the capacity to cope and adapt (Adger et al., 2001). The poor usually have a very low adaptive capacity due to their limited access to information, technology and other capital assets which make them highly vulnerable to climate change. Poverty also constrains the adaptation in other sectors. Poverty, along with infrastructural limitations and other socioeconomic factors, will continue to limit the efforts to conserve biodiversity in South-East Asia (Sodhi et al., 2004). Adaptive capacity in countries where there is a high incidence of poverty will likely remain limited.

Insufficient information and knowledge on the impacts of climate change and responses of natural systems to climate change will likely continue to hinder effective adaptation particularly in Asia. The limited studies on the interconnections between adaptation and mitigation options, costs and benefits of adaptation, and trade-offs between various courses of actions will also likely limit adaptation in Asia. The deficiency in available information and knowledge will continue to make it difficult to enhance public perception of the risks and dangers associated with climate change. In addition, the absence of information on adaptation costs and benefits makes it difficult to undertake the best adaptation option. This limiting factor will be most constraining in developing countries where systems for monitoring and research on climate and responses of natural and human systems to climate are usually lacking. More relevant information such as on the crop yield benefits linked to changes in planting dates for various regions, as reported by Tan and Shibasaki (2003), and on the optimal levels and cost of coastal protection investment in Vietnam, Cambodia and other countries, as reported by Nicholls and Tol (2006), will be needed.

Based on the discussion in Chapter 17, Section 17.4.2.4, it is very likely that in countries of Asia facing serious domestic conflicts, pervasive poverty, hunger, epidemics, terrorism and other pressing and urgent concerns, attention may be drawn away from the dangers of climate change and the need to implement adaptation. The slow change in political and institutional landscape in response to climate change could also be a major limitation to future adaptation. The existing legal and institutional framework in most Asian countries remains inadequate to facilitate implementation of comprehensive and integrated response to climate change in synergy with the pursuit of sectoral development goals.

To address the constraints discussed above and strengthen adaptation in Asia, some of the measures suggested by Stern (2007) could be useful. These include improving access to high-quality information about the impacts of climate change; adaptation and vulnerability assessment by setting in place early warning systems and information distribution systems to enhance disaster preparedness; reducing the vulnerability of livelihoods and infrastructure to climate change; promoting good governance including responsible policy and decision making; empowering communities and other local stakeholders so that they participate actively in vulnerability assessment and implementation of adaptation; and mainstreaming climate change into development planning at all scales, levels and sectors.

10.6 Case studies

10.6.1 Megadeltas in Asia

There are 11 megadeltas with an area greater than 10,000 km^2 (Table 10.10) in the coastal zone of Asia that are continuously being formed by rivers originating from the Tibetan Plateau (Milliman and Meade, 1983; Penland and Kulp, 2005). These megadeltas are vital to Asia because these are home to millions of people, especially the seven megacities that are located in these deltas (Nicholls, 1995; Woodroffe et al., 2006). The megadeltas, particularly the Zhujiang delta, Changjiang delta and Huanghe delta, are also economically important, accounting for a substantial proportion of China's total GDP (Niou, 2002; She, 2004). Ecologically, the Asian megadeltas are critical diverse ecosystems of unique assemblages of plants and animals located in different climatic regions (IUCN, 2003b; ACIA, 2005; Macintosh, 2005; Sanlaville and Prieur, 2005). However, the megadeltas of Asia are vulnerable to climate change and sea-level rise that could increase the frequency and level of inundation of megadeltas due to storm surges and floods from river drainage (Nicholls, 2004; Woodroffe et al., 2006) putting communities, biodiversity and infrastructure at risk of being damaged. This impact could be more pronounced in megacities located in megadeltas where natural ground subsidence is enhanced by human activities, such as in Bangkok in the Chao Phraya delta, Shanghai in the Changjiang delta, Tianjin in the old Huanghe delta (Nguyen et al., 2000; Li et al., 2004a; Jiang, 2005; Li et al., 2005; Woodroffe et al., 2006). Climate change together with human activities could also enhance erosion that has, for example, caused the Lena delta to retreat at a rate of 3.6 to 4.5 m/yr (Leont'yev, 2004) and has affected the progradation and retreat of megadeltas fed by rivers originating from the Tibetan Plateau (Li et al., 2004b; Thanh et al., 2004; Shi et al., 2005; Woodroffe et al., 2006). The adverse impacts of salt-water intrusion on water supply in the Changjiang delta and Zhujiang delta, mangrove forests, agriculture production and freshwater fish catch, resulting in a loss of US\$125x10^6 per annum in the Indus delta could also be aggravated by climate change (IUCN, 2003a, b; Shen et al., 2003; Huang and Zhang, 2004).

Externally, the sediment supplies to many megadeltas have been reduced by the construction of dams and there are plans for many more dams in the 21st century (Chapter 6, Box 6.3; Woodroffe et al., 2006). Reduction of sediment supplies make these systems much more vulnerable to climate change and sea-level rise. When considering all the non-climate pressures, there is very high confidence that the group of populated Asian megadeltas is highly threatened by climate change and responding to this threat will present important challenges (see also Chapter 6, Box 6.3). The sustainability of megadeltas in Asia in a warmer climate will rest heavily on policies and programmes that promote integrated and co-ordinated development of the megadeltas and upstream areas, balanced use and development of megadeltas for conservation and production goals, and comprehensive protection against erosion from river flow anomalies and sea-water actions that combines structural with human and institutional capability building measures (Du and Zhang, 2000; Inam et al., 2003; Li et al., 2004b; Thanh et al., 2004; Saito, 2005; Wolanski, 2007; Woodroffe et al., 2006).

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 in South Asian countries (Pakistan, Nepal, Bhutan, India and Bangladesh). The Gangetic basin alone is home to 500 million people, about 10% of the total human population in the region.

Glaciers in the Himalaya are receding faster than in any other part of the world (see Table 10.9) 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 warming at the current rate. Its total area will likely shrink from the present 500,000 to 100,000 km^2 by the year 2035 (WWF, 2005).

The receding and thinning of Himalayan glaciers can be attributed primarily to 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 have also adversely affected these glaciers. The 30.2 km long Gangotri glacier has been receding alarmingly in recent years (Figure 10.6). Between 1842 and 1935, the glacier was receding at an average of 7.3 m every year; the average rate of recession between 1985 and 2001 is about 23 m per year (Hasnain, 2002). The current trends of glacial melts suggest that the Ganga, Indus, Brahmaputra and other rivers that criss-cross the northern Indian plain could likely become seasonal rivers in the near future as a consequence of climate change and could likely affect the economies in the region. Some other glaciers in Asia – such as glaciers shorter than 4 km length in the Tibetan Plateau – are projected to disappear and the glaciated areas located in the headwaters of the Changjiang River will likely decrease in area by more than 60% (Shen et al., 2002).

Table 10.9. *Record of retreat of some glaciers in the Himalaya.*

Glacier	Period	Retreat of snout (metre)	Average retreat of glacier (metre/year)
Triloknath Glacier (Himachal Pradesh)	1969 to 1995	400	15.4
Pindari Glacier (Uttaranchal)	1845 to 1966	2,840	135.2
Milam Glacier (Uttaranchal)	1909 to 1984	990	13.2
Ponting Glacier (Uttaranchal)	1906 to 1957	262	5.1
Chota Shigri Glacier (Himachal Pradesh)	1986 to 1995	60	6.7
Bara Shigri Glacier (Himachal Pradesh)	1977 to 1995	650	36.1
Gangotri Glacier (Uttaranchal)	1977 to 1990	364	28.0
Gangotri Glacier (Uttaranchal)	1985 to 2001	368	23.0
Zemu Glacier (Sikkim)	1977 to 1984	194	27.7

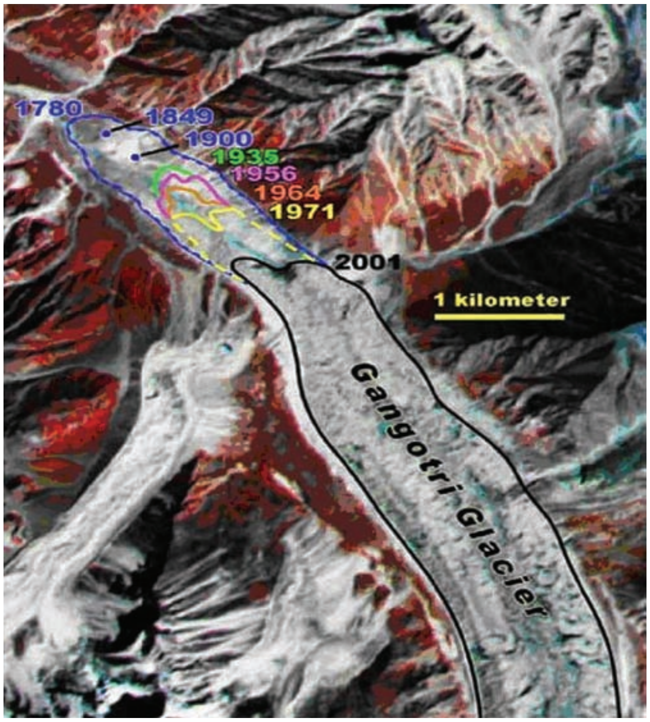


Figure 10.6. *Composite satellite image showing how the Gangotri Glacier terminus has retracted since 1780 (courtesy of NASA EROS Data Center, 9 September 2001).*

10.7 Implications for sustainable development

Chapter 20, Section 20.1 of this volume uses the succinct definition of the Bruntland Commission to describe sustainable development as *"development that meets the needs of the present without compromising the ability of future generations to meet their own needs"*. Sustainable development represents a balance between the goals of environmental protection and human economic development and between the present and future needs. It implies equity in meeting the needs of people and integration of sectoral actions across space and time. This section focuses mainly on how the impacts of projected climate change on poverty eradication, food security, access to water and other key concerns described above will likely impinge on the pursuit of sustainable development in Asia. In most instances, the reference to sustainable development will be confined to a specific country or sub-region, primarily due to the existing difficulty of aggregating responses to climate change and other stressors across the whole of Asia.

10.7.1 Poverty and illiteracy

A significant proportion of the Asian population is living below social and economic poverty thresholds. Asia accounts for more than 65% of all people living in rural areas without access to sanitation, of underweight children, of people living on less than a dollar a day and of TB cases in the world. It accounts for over 60% of all malnourished people, people without access to sanitation in urban areas and people without access to water in rural areas (UN-ESCAP, 2006). Most of the world's poor reside in South Asia and, within South Asia, the majority resides in rural areas (Srinivasan, 2000). Greater inequality could both undermine the efficiency with which future growth could reduce poverty and make it politically more difficult to pursue pro-poor policies (Fritzen, 2002).

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 macroscale environmental deterioration. In the absence of opportunities for engaging in stable and gainful livelihood, poverty stricken communities are left with no option but to utilise even the disaster-prone areas, unproductive lands and ecologically fragile lands that have been set aside for protection purposes such as conservation of biodiversity, soil and water. With climate change, the poor sectors will be most vulnerable and, without appropriate measures, climate change will likely exacerbate the poverty situation and continue to slow down economic growth in developing countries of Asia (Beg et al., 2002).

10.7.2 Economic growth and equitable development

Rapid economic growth characterised by increasing urbanisation and industrialisation in several countries of Asia (i.e., China, India and Vietnam) will likely drive the increase in the already high demand for raw materials such as cement, wood, steel and other construction materials in Asia. Consequently, the use of forests, minerals and other natural resources will increase along with the increase in carbon emission. The challenge here is finding the development pathways wherein GHG emission is minimised while attaining high economic growth (Jiang et al., 2000). Equally vital in this regard is the promotion of equity in spreading the benefits that will arise from economic growth so as to uplift the condition of the poor sector to a state of enhanced capacity to adapt to climate change. Another concern related to economic growth is the increase in the value of land to a level where it becomes economically less profitable to farm agricultural land than using the land for industrial and commercial purposes. In the absence of appropriate regulatory intervention, this can undermine the production of adequate food supply and further jeopardise the access of the poor to food support.

Sustaining economic growth in the context of changing climate in many Asian countries will require the pursuit of enhancing preparedness and capabilities in terms of human, infrastructural, financial and institutional dimensions with the aim in view of reducing the impacts of climate change on the economy. For instance, in many developing countries, instituting financial reforms could likely result in a more robust economy that is likely to be less vulnerable to changing climate (Fase and Abma, 2003). In countries with predominantly agrarian economies, climate change, particularly an increase in temperature and reduction in precipitation, could, in the absence of adequate irrigation and related infrastructural interventions, dampen the economic growth by reducing agricultural productivity (Section 10.4.1).

10.7.3 Compliance with and governance of Multilateral Environmental Agreements

Many countries in Asia are signatories to one or more of the Multilateral Environmental Agreements (MEAs) that seek to address common concerns such as biodiversity conservation and sustainable forest management, climate change, international water resources, over-exploitation of regional fisheries, trans-boundary air pollution, and pollution of regional seas. Some of these MEAs include the United Nations Framework Convention on Climate Change (UNFCCC), the Convention on Biological Diversity (CBD), the Convention to Combat Desertification (CCD), the Convention on International Trade of 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, International Tropical Timber Organization (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 take advantage of opportunities in designing integrated and synergistic responses in adherence to and compliance with the terms and conditions of MEAs and improve environmental quality without unduly hampering economic development (Beg et al., 2002).

10.7.4 Conservation of natural resources

Natural resources utilisation could intensify in several parts of Asia in response to increasing demands. In South-East Asia, intensification of forest utilisation could likely increase further the already high rate of deforestation that could lead to the loss of much of its original forests and biodiversity by 2100 (Sodhi et al., 2004). To sustain development in this region, measures to minimise deforestation and enhance restoration of degraded forests will be required. The challenge in Asia will be in countries with developing economies where the need to maximise production could lead to increased perturbations of the ecosystems and the environment that could be aggravated by climate change. In the same manner, the use of water will continue to increase as the population and economies of countries grow. This will likely put more stress on water that could be exacerbated by climate change as discussed above. Integrated responses to cope with the impacts of climate change and other stressors on the supply and demand side will likely contribute in the attainment of sustainable development in many countries in the West, South and South-East Asia.

10.8 Key uncertainties, research gaps and priorities

10.8.1 Uncertainties

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 socio-economics of the countries in the region and could be strongly dependent on development pathways followed by individual nations. Inaccurate description on future scenarios of socio-economic change, environmental change, land-use change and technological advancement and its impacts will lead to incorrect GHG emissions scenarios. Therefore factors affecting design of social development scenarios need to be examined more carefully to identify and properly respond to 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

Table 10.10. *Megadeltas of Asia.*

Features	Lena	Huanghe-Huaihe	Changjiang	Zhujiang	Red River	Mekong	Chao Phraya	Irrawaddy	Ganges-Brahmaputra	Indus	Shatt-el-Arab (Arvand Rud)
Area (10^3 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	33.3	905	326	120	470	30	430	1330	185	46
Sediment load (10^6 t/yr)	18	849	433	76	130	160	11	260	1969	400	100
Delta growth (km^2/yr)	--	21.0	16.0	11.0	3.6	1.2		10.0	5.5 to 16.0	PD30	
Climate zone	Boreal	Temperate	Sub-tropical	Sub-tropical	Tropical	Tropical	Tropical	Tropical	Tropical	Semi-arid	Arid
Mangroves (10^3 km^2)	None	None	None	None		5.2	2.4	4.2	10	1.6	None
Population (10^6) in 2000	0.000079	24.9 (00)	76 (03)	42.3 (03)	13.3	15.6	11.5	10.6	130	3.0	0.4
Population increase by 2015	None	18	-	176	21	21	44	15	28	45	--
GDP (US\$$10^9$)		58.8 (00)	274.4 (03)	240.8 (03)	9.2 (04)	7.8 (04)	--	--	--	--	--
Megacity	None	Tianjin	Shanghai	Guangzhou	--	--	Bangkok	--	Dhaka	Karachi	--
Ground subsidence (m)	None	2.6 to 2.8	2.0 to 2.6	X	XX	--	0.2 to 1.6	--	0.6 to 1.9 mm/a		--
SLR (cm) in 2050	10 to 90 (2100)	70 to 90	50 to 70	40 to 60	--	--	--	--	--	20 to 50	--
Salt-water intrusion (km)	--	--	100	--	30 to 50	60 to 70	--	--	100	80	--
Natural hazards	--	FD	CS, SWI, FD	CS, FD, SWI	CS, FD, SWI	SWI	--	--	CS, FD, SWI	CS, SWI	--
Area inundated by SLR (10^3 km^2). Figure in brackets indicates amount SLR.	--	21.3 (0.3m)	54.5 (0.3m)	5.5 (0.3m)	5 (1m)	20 (1m)	--	--	--	--	--
Coastal protection	No protection	Protected	Protected	Protected	Protected	Protected	Protected	Protected	Protected	Partial Protection	Partial protection

PD: Progradation of coast; CS: Tropical cyclone and storm surge; FD: Flooding; SLR: Sea-level rise; SWI: Salt water intrusion; DG: Delta growth in area; XX: Strong ground subsidence; X: Slight ground subsidence; --: No data available

spatial variability of all forcing mechanisms and their connections to global, hemispheric and regional responses.

Uncertainty in assessment methodologies per se is also one of the main sources of uncertainty. In model-based assessments, results on impacts of climate change, in fact, accumulate errors from the methodologies for establishment of socio-economic scenarios, environmental scenarios, climate scenarios and climate impact assessment (Challinor et al., 2005).

10.8.2 Confidence levels and unknowns

The vulnerability of key sectors to the projected climate change for each of the seven sub-regions 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 10.11. The assigned confidence levels could provide guidance in weighing which of the sectors ought to be

Table 10.11. *Vulnerability of key sectors to the impacts of climate change by sub-regions in Asia.*

Sub-regions	Food and fibre	Biodiversity	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 and West 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
South-East 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

the priority concerns based on the most likely future outcomes. However, 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. 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 (Preston et al., 2006).

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 metres in the next two centuries (Hulbe and Payne, 2001).

10.8.3 Research gaps and priorities

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. These include (a) the future usage of fossil fuels, (b) the future emissions of methane (Slingo et al., 2005; Challinor et al., 2006), (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 conduct innovative research on the response of human and natural systems to multiple stresses at various levels and scales. Key specific research-related priorities for Asia are:

- basic physiological and ecological studies on the effects of changes in atmospheric conditions;
- enhancing capability to establish and maintain observation facilities and to collect, and compile, climatic, social and biophysical data;
- improvement of information-sharing and data networking on climate change in the region;
- impacts of extreme weather events such as disasters from flood, storm surges, sea-level rise, heatwaves, plant diseases and insect pests;
- identification of social vulnerability to multiple stressors due to climate change and environmental change;
- adaptation researches concerning agro-technology, water resources management, integrated coastal zone management; pathology and diseases monitoring and control;
- sectoral interaction such as between 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;
- mainstreaming science of climate change impacts, adaptation and vulnerability in policy formulation; and
- identification of the critical climate thresholds for various regions and sectors.

References

ABI, 2005: Financial Risks of Climate Change, Summary Report. Association of British Insurers, London, 40 pp. http://www.abi.org.uk/Display/File/Child/552/Financial_Risks_of_Climate_Change.pdf.

Abu-Taleb, M.F., 2000: Impacts of global climate change scenarios on water supply and demand in Jordan. *Water International*, **25**, 457-463.

Achard, F., H.J. Stibig, L. Laestadius, V. Roshchanka, A. Yaroshenko and D. Aksenov, Eds., 2005: Identification of 'hotspot areas' of forest cover changes in boreal Eurasia. Office for Official Publication of the European Communities, Luxembourg, EUR 21681 EN, 64 pp. http://www-tem.jrc.it//PDF_publis/2005/Achard&al_HotSpot-Boreal-Eurasia.pdf.

ACIA (Arctic Climate Impact Assessment), 2005: *Impacts of a Warming Arctic: Arctic Climate Impact Assessment*. Cambridge University Press, Cambridge, 140 pp.

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

ADB (Asian Development Bank), 2002: *Key Indicators 2002: Population and Human Resource Trends and Challenges*. Asian Development Bank, Manila, 474 pp.

Adger, N., 2000: Social and ecological resilience: are they related? *Prog. Hum. Geog*, **24**, 347-364.

Adger, N., 2003: Social capital, collective action, and adaptation to climate change. *Econ. Geog.*, **79**, 387-404.

Adger, W.N., P.M. Kelly and N.H. Ninh, Eds., 2001: *Living with Environmental Change: Social Vulnerability, Adaptation and Resilience in Vietnam*. Routledge, London, 314 pp.

Aggarwal, P.K., 2003: Impact of climate change on Indian agriculture. *Journal of Plant Biology*, **30**, 189-198.

Aggarwal, 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 Agr.*, **29**, 259-268.

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

Alcamo, J., N. Dronin, M. Endejan, G. Golubev and A. Kirilenko, 2004: A new perspective on the impacts of climate change on Russian agriculture and water resources. *Proc. World Climate Change Conference, Moscow*, Y. Izrael, G. Gruza, S. Semenov and I. Nazarov, Eds., Institute of Global Climate and Ecology, Moscow, 324-335.

Aldhous, P., 2004: Borneo is burning. *Nature*, **432**, 144-146.

Ali, A., 1999: Climate change impacts and adaptation assessment in Bangladesh. *Climate Res.*, **12**, 109-116.

Allen, K.M., 2006: Community-based disaster preparedness and climate adaptation: local capacity building in the Philippines. *Disasters*, **30**, 81-100.

Alley, R.B., 2002: Climate change: enhanced: on thickening ice? *Science*, **295**, 451-452.

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

Antonov, J.I., S. Levitus and T.P. Boyer, 2002: Steric sea level variations during 1957–1994: Importance of salinity. *J. Geophys. Res.*, **107**, 8013, doi:10.1029/2001JC000964.

Arceo H.O., M.C. Quibilan, P.M. Alino, G. Lim and W.Y. Licuanan, 2001: Coral bleaching in Philippine reefs: coincident evidences with Mesoscale thermal anomalies. *B. Mar. Sci.*, **69**, 579- 593.

Archer, D.R. and H.J. Fowler, 2004: Spatial and temporal variations in precipitation in the Upper Indus Basin, global teleconnections and hydrological implications. *Hydrol. Earth Syst. Sc.*, **8**, 47-61.

Arendt, A.A., K.A. Echelmeyer, W.D. Harrison, C.S. Lingle and V.B. Valentine, 2002: Rapid wastage of Alaska glaciers and their contribution to rising sea level. *Science*, **297**, 382–386.

Arnell, N.W., 2004: Climate change and global water resources: SRES emissions and socio-economic scenarios. *Global Environ.l Chang.*, **14**, 13-52.

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**, 608-619.

Barnett, J., 2003: Security and climate change. *Global Environ. Chang.*, **13**, 7-17.

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, 36-47.

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

Batima, P., L. Natsagdorj, P. Gombluudev and B. Erdenetsetseg, 2005a: Observed climate change in Mongolia. *AIACC Working Paper*, **13**, 25 pp.

Batima, P., T. Ganbaatar, D. Tumerbaatar, B. Erdenetsetseg, B. Bolortsetseg, B. Gantsetseg, G. Sanjid and S. Khudulmur, 2005b: Climate change impacts on environment. *Climate Change Impacts*, P. Batima and B. Bayasgalan, Eds., Admon publishing, Ulaanbaatar, 59-115.

Batima P., B. Bat, S. Tserendash, L. Bayarbaatar, S. Shiirev-Adya, G. Tuvaansuren, L. Natsagdorj, and T. Chuluun, 2005c: Adaptation to Climate Change, Batima P. and D. Tserendorj, Eds., Admon Publishing, Ulaanbaatar, 90 pp.

Beg, N., J.C. Morlot, O. Davidson, Y. Afrane-Okesse, L. Tyani, F. Denton, Y. Sokona, J.P. Thomas, E.L. La Rovere, J.K. Parikh, K. Parikh and A. Atiq Rahman, 2002: Linkages between climate change and sustainable development. *Climate Policy*, **2**, 129-144.

Bhadra, B., 2002: Regional cooperation for sustainable development of Hindu Kush Himalaya region: opportunities and challenges. *Paper presented at the Alpine Experience – An Approach for other Mountain Regions*, Berchtesgaden.

Blaikie, P.M., T. Cannon, I. Davis and B. Wisner, 1994: *At Risk: Natural Hazards, People's Vulnerability, and Disasters*. Routledge, New York, 320 pp.

Boer, R. and A. Faqih, 2004: Current and future rainfall variability in Indonesia. In An Integrated Assessment of Climate change Impacts, Adaptation and Vulnerability in Watershed Areas and Communities in Southeast Asia, Report from AIACC Project No. AS21 (Annex C, 95-126). International START Secretariat, Washington, District of Columbia. http://sedac.ciesin.columbia.edu/cgi-bin/aiacc.

Boo, K.O., W.T. Kwon and J.K. Kim, 2004: Vegetation change in regional surface climate over East Asia due to global warming using BIOME 4. *Nuovo Cimento*, **27**, 317-327.

Bou-Zeid, E. and M. El-Fadel, 2002: Climate change and water resources in Lebanon and the Middle East. *J. Water Res. Pl.-ASCE*, **128**, 343-355.

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. *Trop. Med. Int. Health*, **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., L. Selig and M. Spalding, 2002: Reefs at Risk in Southeast Asia Data CD. Accessed: 15.05.07: http://www.wri.org/biodiv/pubs_description.cfm?PubID=3144.

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

Callaghan, T.V., L.O. Björn, Y.I. Chernov, F.S. Chapin III, T.R. Christensen, B. Huntley, R. Ims, M. Johansson, D. Jolly, N.V. Matveyeva, N. Panikov, W.C. Oechel and G.R. Shaver, 2005: Arctic tundra and polar ecosystems. *Arctic Climate Impact Assessment*, ACIA. Cambridge University Press, Cambridge, 243-352.

Challinor, A., T. Wheeler, J. Sling and D. Hemming, 2005: Quantification of physical and biological uncertainty in the simulation of the yield of a tropical crop using present day and doubled CO_2 climates. *Philos. T. Roy. Soc. B*, **360**, 2085-2094.

Challinor, A.J., T.R. Wheeler, T.M. Osborne and J.M. Slingo, 2006: Assessing the vulnerability of crop productivity to climate change thresholds using an integrated crop-climate model. *Avoiding Dangerous Climate Change*, J. Schellnhuber, W. Cramer, N. Nakićenović, G. Yohe and T.M.L. Wigley, Eds., Cambridge University Press, Cambridge, 187-194.

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

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

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**, 442-450.

Chen, J., Z.S. An and L.W. Liu, 2001: Variations in chemical compositions of the aeolian dust in Chinese Loess Plateau over the past 2.5 Ma and chemical weathering in the Asian inland. *Sci. China Ser. D*, **44**, 403-413.

Chen, X.Q., 1991: Sea-level changes since the early 1920s from the long records of two tidal gauges in Shanghai, China. *J. Coastal Res.*, **7**, 787-799.

Cheng G. and T. Wu, 2007: Responses of permafrost to climate change and their environmental significance, Qinghai-Tibet Plateau. *J. Geophys. Res.*, **112**, F02S03, doi:10.1029/2006JF000631.

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.

Christensen, J.L., B. Hewitson, A. Busuioc, A. Chen, X. Gao, I. Held, R. Jones, K. Rupa Kumar and Co-authors, 2007: Regional climate projections. *Climate Change 2007: The Scientific Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, S. Solomon, D. Qin, M. Manning, Z. Chen, K. Averyt, M. Marquis, K.B.M. Tignor and H.L. Miller, Eds., Cambridge University Press, Cambridge, 847-940.

Christensen, L., M.B. Coughenour, J.E. Ellis and Z.Z. Chen, 2004: Vulnerability of the Asian typical steppe to grazing and climate change. *Climatic Change*, **63**, 351-368.

Chua, T.E., 1999: Marine pollution prevention and management in the East Asian seas: a paradigm shift in concept, approach and methodology. *Mar. Pollut. Bull.*, **39**, 1-12.

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

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

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. Pulhin and K.B. Garcia, 2006: Climate change impact on water resources in Pantabangan Watershed, Philippines. AIACC Final Technical Report, 9-107. http://www.aiaccproject.org/FinalReports/final_reports.html.

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

Dartmouth Flood Observatory, 2003: Dartmouth Flood Observatory - Flood Analysis Report 2003-118: Sri Lanka - Heavy monsoon rains - Flooding and mudslides. http://www.dartmouth.edu/~floods/images/2003118sum.htm.

De, U.S. and R.K. Mukhopadhyay, 1998: Severe heat wave over the Indian subcontinent in 1998 in perspective of global climate. *Curr. Sci.*, **75**, 1308-1315.

De Grandi, G.F., Y. Pauste, F. Achard and D, Mollicone, 2003: The GBFM Radar Mosaic of the Eurasian Taiga: groundwork for the bio-physical characterization of an ecosystem with relevance to global change studies. *Proc. International Geoscience and Remote Sensing Symposium,* Toulouse, 176.

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

Ding, Z.Q. and H.S. Pan, 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. *Agr. Water Manage.*, **66**, 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, J. and Y.C. Ma, 2004: Climatic trend of rainfall over Tibetan Plateau from 1971 to 2000. *Acta Geographica Sinica*, **59**, 375-382.

Duedall, I.W. and G.A. Maul, 2005: Demography of coastal populations. *Encyclopedia of Coastal Science*, M.L. Schwartz, Ed., Springer, Dordrecht, 368-374.

Dumnov A.D., Y.I. Maksimov, Y.V. Rochupkina and O.A. Aksenova, 2005: *Forest fires in the Russian Federation (statistical book)*. NIA-Nedra, Moscow, 327 pp. (In Russian).

Duong, L.C., 2000: Lessons from severe tropical storm Linda. *Workshop report: The Impact of El Niño and La Niña on Southeast Asia*, 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**, 1544-1548.

Dyurgerov, M.B. and M.F. Meier, 2000 Twentieth century climate change: evidence from small glaciers. *P. Natl. Acad. Sci. USA*., **97**, 1406–1411.

Ebi, K, T.J. Teisberg, L.S. Kalkstein, L. Robinson and R.F. Weiher, 2004: Heat watch/warning systems save lives. *B. Am. Meteorol. Soc.*, **85**, 1067-1073.

El-Zein, A., M. Tewtel-Salem and G. Nehme, 2004: A time-series analysis of mortality and air temperature in Greater Beirut. *Sci. Total Environ.*, **330**, 71–80.

Emanuel, K., 2005: Increasing destructiveness of tropical cyclones over the past 30 years. *Nature*, **436**, 686-688.

Emori, S., T. Nozawa, A. Numaguchi and I. Uno, 2000: A regional climate change projection over East Asia. Preprints, *11th Symposium on Global Change Studies*, Long Beach, California, 15-18.

Environment News Service, 2002: Hungry Cambodians at the mercy of climate change. Phnom Penh, 26 November 2002. Accessed 16.05.07: http://www.ens-newswire.com/ens/nov2002/2002-11-26-02.asp.

Erdnethuya, M., 2003: Forest and steppe fires in Mongolia - potential impacts of climate change, vulnerability and adaptation assessment for grassland ecosystem and livestock sector in Mongolia, Annual AIACC Project Report.

Ericson, J.P., C.J. Vorosmarty, S.L. Dingman, L.G. Ward and M. Meybeck, 2005: Effective sea-level rise and deltas: causes of change and human dimension implications. *Global Planet. Change*, **50**, 63-82.

Faisal, I.M. and S. Parveen, 2004: Food security in the face of climate change, population growth and resource constraints: implications for Bangladesh. *Environ. Manage.*, **34**, 487-498.

Fan, D.D. and C.X. Li, 2005: Complexities of Chinese coast in response to climate change. *Advance in Research on Climate Change*, **1**, 111-114 (in Chinese with an English abstract).

FAO (Food and Agriculture Organization), 2003: *World Agriculture: Towards 2015/2030. An FAO Perspective*. Bruinsma, Ed., FAO, Rome and Earthscan, London, 520 pp.

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, 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, 206 pp.

FAO (Food and Agriculture Organization), 2004c: Data Base. Food and Agriculture Organization of the United Nations, Rome.

FAO (Food and Agriculture Organization), 2005: Special event on impacts of climate change, pests and diseases on food security and poverty reduction. *Background document 31st Session of the Committee on World Food Security*, Rome, 10 pp.

FAO/WFP (Food and Agriculture Organization/World Food Programme), 2000: FAO/WFP crop and food supply assessment mission to Cambodia. Special Report X9237/E, 29 December 2000, FAO Global Information and Early Warning System on Food and Agriculture/World Food Programme, 14 pp.

Farooq, A.B. and A.H. Khan, 2004: Climate change perspective in Pakistan. *Proc. Capacity Building APN Workshop on Global Change Research*, Islamabad, 39-46.

Fase, M.M.G. and R.C.N. Abma, 2003: Financial environment and economic growth in selected Asian countries. *Journal of Asian Economics*, **14**, 11-21.

Fedorov, A. and P. Konstantinov, 2003: Observations of surface dynamics with thermokarst initiation, Yukechi site, Central Yakutia. *Proc. 7th International Conference on Permafrost*, Québec, 239-243.

FFARF (Federal Forest Agency of the Russian Federation), 2004: *State Forest Account of Russia for the Year 2003*. Russian Scientific Research Centre, Lesresurs, Moscow, 633 pp. (In Russian).

Fischer, G., M. Shah and H. van Velthuizen, 2002: Climate change and agricultural vulnerability. Preprints, *World Summit on Sustainable Development*, Johannesburg, 160 pp.

Fitzharris, B.B., 1996: The cryosphere: changes and their impacts. *Climate Change 1995: Impacts, Adaptations and Mitigation of Climate Change: Scientific-Technical Analyses. Contribution of Working Group II to the Second Assessment Report of the Intergovernmental Panel on Climate Change*, R.T. Watson, M.C. Zinyowera, O.F. Canziani, M. Petit, S.K. Sharma, H. Tsukamoto, P. Vellinga, M. Beniston and A. Hentati, Eds., Cambridge University Press, Cambridge, 241-265.

FNCRF, 2006: *Fourth National Communication of Russian Federation Under the United Nations Framework Convention on Climate Change*. Interagency Commission of the Russian Federation on Climate Change Problems, Moscow, 147 pp.

Fritzen, S., 2002: Growth, inequality and the future of poverty reduction in Vietnam. *Journal of Asian Economics*, **13**, 635-657.

Frolov, I., G. Alekseev and A. Danilov, 2004: Climate change in polar areas. *Proc. World Climate Change Conference, Moscow*, Y. Izrael, G. Gruza, S. Semenov and I. Nazarov, Eds., Institute of Global Climate and Ecology, Moscow, 484-490.

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.

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**, 458-463 (In Chinese with English abstract).

Gavriliev, P.P. and P.V. Efremov, 2003: Effects of cryogenic processes on Yakutian landscapes under climate warming. *Proc. 7th International Conference on Permafrost*, Québec, 277-282.

GCOS, 2005a: GCOS Regional Action Plan for South and South-East Asia. http://www.wmo.int/pages/prog/gcos/documents/GCOS_ESEA_RAP_FINAL-DRAFT_Sept2005.pdf

GCOS, 2005b: GCOS Regional Action Plan for South and South-West Asia. http://www.wmo.int/pages/prog/gcos/documents/GCOS_SSWA_RAP_FINAL-DRAFT_Sept2005.pdf

Ge, D.K., Z.O. Jin, C.L. Shi and L.Z. Gao, 2002: Gradual impacts of climate change on rice production and adaptation strategies in southern China, Jiangsu. *J. Agr. Sci*., **18**, 1-8.

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

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

Goldammer, J.G., A.I. Sukhinin and I. Csiszar, 2003: The current fire situation in the Russian Federation. *International Forest Fire News*, **29**, 89-111.

Golitsyn, G.S. and I.A. Yu, Eds., 2002: *Global Climate Change and Its Impacts on Russia*. Ministry of Industry and Science, Moscow, 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 Centre for Environmental Systems Research, University of Kassel and Department of Geography, Moscow State University, Moscow, 25 pp.

Gopal, B., 2003: Future of wetlands in Asia. *Abstract, 5th Int. Conf. on Environmental Future, Zürich*. http://www.icef.eawag.ch/abstracts/Gopal.pdf.

Gruza, G. and E. Rankova, 2004: Detection of changes in climate state, climate variability and climate extremity. *Proc. World Climate Change Conference, Moscow*, Y. Izrael, G. Gruza, S. Semenov and I. Nazarov, Eds., Institute of Global Climate and Ecology, Moscow, 90-93.

Gruza, G., E. Rankova, V. Razuvaev and O. Bulygina, 1999: Indicators of climate change for the Russian Federation. *Climatic Change*, **42**, 219-242.

Guo, Q.X., J.L. Li, J.X. Liu and Y.M. Zhang, 2001: The scientific significance of the forest vegetation ecotone between Daxing'an and Xiaoxing'an mountains to global climate change study. *J. Forest*., **29**, 1-4.

Gupta, S.K. and R.D. Deshpande, 2004: Water for India in 2050: first-order assessment of available options. *Curr. Sci. India*, **86**, 1216-1224.

Hajima T., Y. Shimizu, Y. Fujita and K. Omasa, 2005: Estimation of net primary production in Japan under nitrogen-limited scenario using BGGC Model. *Journal of Agricultural Meteorology*, **60**, 1223-1225.

Hales, S, N., de Wet, J. Maindonald and A. Woodward, 2002: Potential effect of population and climate changes on global distribution of dengue fever: an empirical model. *Lancet*, **360**, 830-834.

Hamilton, J.M., D.J. Maddison and R.S.J. Tol, 2005: Climate change and international tourism: a simulation study. *Global Environ. Chang*., **15**, 253-266.

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

Hara, Y., K. Takeuchi and S. Okubo, 2005: Urbanization linked with past agricultural landuse patterns in the urban fringe of a deltaic Asian mega-city: a case study in Bangkok. *Landscape Urban Plan*., **73**, 16-28.

Harasawa, H. and S. Nishioka, Eds., 2003: Climate Change on Japan, KokonShoin Publications, Tokyo (In Japanese).

Hasnain, S.I., 2002: Himalayan glaciers meltdown: impacts on South Asian Rivers. *FRIEND 2002-Regional Hydrology: Bridging the Gap between Research and Practice*, H.A.J. van Lanen and S. Demuth, Eds., IAHS Publications, Wallingford, No. 274, 417-423.

Hasumi, H. and S. Emori, Eds., 2004: K-1 coupled model (MIROC) description. K-1 Technical Report 1, Centre for Climate System Research, University of Tokyo, Tokyo, 34 pp.

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

Higashi, H., K. Dairaku and T. Matuura, 2006: Impacts of global warming on heavy precipitation frequency and flood risk. *Journal of Hydroscience and Hydraulic Engineering*, **50**, 205-210.

Hinzman, L.D., D.L. Kane, K. Yoshikawa, A. Carr, W.R. Bolton and M. Fraver, 2003: Hydrological variations among watersheds with varying degrees of permafrost. *Proc. 7th International Conference on Permafrost*, Québec, 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.

Hoanh, C.T., H. Guttman, P. Droogers and J. Aerts, 2004: Will we produce sufficient food under climate change? Mekong Basin (South-east Asia). *Climate Change in Contrasting River Basins: Adaptation Strategies for Water, Food, and Environment*, J.C.J.H. Aerts and P. Droogers, Eds., CABI Publishing, Wallingford, 157-180.

Honda, Y., M. Ono, I. Uchiyama and A. Sasaki, 1995: Relationship between daily high temperature and mortality in Kyushu, Japan. *Nippon Koshu Eisei Zasshi*, **42**, 260-268.

Honda, Y., H. Nitta and M. Ono, 2003: Low level carbon monoxide and mortality of persons aged 65 or older in Tokyo, Japan, 1976-1990. *J. Health Sci*., **49**, 454-458.

Hu, D.X., W.Y. Han and S. Zhang, 2001: *Land-Ocean Interaction in Changjiang and Zhujiang Estuaries and Adjacent Sea Areas*. China Ocean Press, Beijing, 218 pp. (in Chinese).

Hu, Z.Z., S. Yang and R. Wu, 2003: Long-term climate variations in China and global warming signals. *J. Geophys. Res*., **108**, 4614, doi:10.1029/2003JD003651.

Huang, H.J., F. Li, J.Z. Pang, K.T. Le and S.G. Li, 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 X.D. Xie, 2000: *Sea Level Changes in Guangdong and Its Impacts and Strategies*. Guangdong Science and Technology Press, Guangzhou, 263 pp.

Huang, Z.G. and W.Q. Zhang, 2004: Impacts of artificial factors on the evolution of geomorphology during recent 30 years in the Zhujiang Delta. *Quaternary Research*, **24**, 394-401.

Hughes, T.P., A.H. Baird, D.R. Bellwood, M. Card, S.R. Connolly, C. Folke, R. Grosberg, O. Hoegh-Guldberg and Co-authors, 2003: Climate change, human impacts, and the resilience of coral reefs. *Science*, **301**, 929-933.

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

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, 160 pp.

Inam, A., T.M. Ali Khan, A.R. Tabrez, S. Amjad, M. Danishb and S.M. Tabrez, 2003: Natural and man-made stresses on the stability of Indus deltaic Eco region. *Extended Abstract, 5th International Conference on Asian Marine Geology*, Bangkok, Thailand (IGCP475/APN).

India Meteorological Department, 2002 to 2006: Southwest Monsoons of 2002, 2003, 2004, 2005 and 2006 - end of season reports. Published by India Meteorological Department, Government of India, Pune.

India Meteorological Department, 2006: Southwest Monsoon 2006 - end of season report. Published by India Meteorological Department, Government of India, Pune.

IPCC, 1992: *Climate Change 1992: The Supplementary Report to the IPCC Scientific Assessment*. J.T. Houghton, B.A. Callander and S.K. Varney, Eds., Cambridge University Press, Cambridge, 200 pp.

IPCC, 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*, J.J. McCarthy, O.F. Canziani, N.A. Leary, D.J. Dokken and K.S. White, Eds., Cambridge University Press, Cambridge, 1032 pp.

IRIMO, 2006a: Country Climate Analysis in year 2005, Islamic Republic of Iran Meteorological Organization, Tehran.

IRIMO, 2006b: Country Climate Analysis in spring 2006, Islamic Republic of Iran Meteorological Organization, Tehran.

Isaev, A., V. Stolbovoi, V. Kotlyakov, S. Nilsson and I. McCallum, 2004: Climate change and land resources of Russia. *Proc. World Climate Change Conference, Moscow*, Y. Izrael, G. Gruza, S. Semenov and I. Nazarov, Eds., Institute of Global Climate and Ecology, Moscow, 234-240.

Ishigami, Y., Y. Shimizu and K. Omasa, 2003: Projection of climatic change effects on potential natural vegetation distribution in Japan. *Journal of Agricultural Meteorology*, **59**, 269-276 (in Japanese with an English abstract).

Ishigami, Y., Y. Shimizu and K. Omasa, 2005: Evaluation of the risk to natural vegetation from climate change in Japan. *Journal of Agricultural Meteorology*, **61**, 69-75 (in Japanese with an English abstract).

Isobe, H., 2002: Trends in precipitation over Japan. *Proc. 6th Symposium on Water Resources*, 585-590.

IUCN (The World Conservation Union), 2003a: Indus Delta, Pakistan: economic costs of reduction in freshwater flows. Case Studies in Wetland Valuation No. 5, Pakistan Country Office, Karachi, 6 pp. Accessed 24.01.07: www.waterandnature.org/econ/CaseStudy05Indus.pdf.

IUCN (The World Conservation Union), 2003b: The lower Indus river: balancing development and maintenance of wetland ecosystems and dependent livelihoods. Water and Nature Initiative, 5 pp. Accessed 24.01.07: www.iucn.org/themes/wani/flow/cases/Indus.pdf.

Izmerov, N.F., B.A. Revich and E.I. Korenberg, Eds., 2004: *Proc. Intl. Conf. Climate Change and Public Health in Russia in the 21st Century*. Russian Academy of Medical Sciences - Russian Regional Committee for Cooperation with UNEP Centre for Demography and Human Ecology Russian Regional Environmental Centre Non-Governmental Organisation 'Environmental Defence', Moscow, 461 pp.

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

Izrael, Y.A. and Y.A. Anokhin, 2000: Monitoring and assessment of the environment in the Lake Baikal region. *Aquatic Ecosystem Health and Management*, **3**, 199-202.

Izrael, Y.A. and Y.A. Anokhin, 2001: Climate change impacts on Russia. *Integrated Environmental Monitoring*, Nauka, Moscow, 112-127 (in Russian with an English abstract).

Izrael, Yu. A. and O.D. Sirotenko, 2003, Modeling climate change impact on agriculture of Russia. *Meteorology and Hydrology*, **6**, 5-17.

Izrael, Y.A., and others, Eds. 2002a: *Third National Communication of the Russian Federation*. Inter-agency Commission of the Russian Federation of Climate Change, Moscow, 142 pp. http://unfccc.int/resource/docs/natc/rusnce3.pdf.

Izrael, Y.A., Y.A. Anokhin and A.V. Pavlov, 2002b: Permafrost evolution and the modern climate change. *Meteorology and Hydrology*, **1**, 22-34.

Izrael, Yu., A.V. Pavlov, Yu. A. Anokhin, L.T. Miach and B.G. Sherstiukov, 2006: Statistical evaluation of climate change on permafrost terrain in the Russian Federation. *Meteorology and Hydrology*, **5**, 27-38.

Japan Meteorological Agency, 2005: Global Warming Projection, Vol.6 - with the RCM20 and with the UCM, 58 pp. (in Japanese).

Jiang, H.T., 2005: Problems and discussion in the study of land subsidence in the Suzhou-Wuxi-Changzhou Area. *Quaternary Res*., **25**, 29-33.

Jiang, K., T. Masui, T. Morita and Y. Matsuoka, 2000: Long-term GHG emission scenarios for Asia -Pacific and the world. *Technol. Forecast. Soc*., **63**, 207-229.

Jin, Z.Q., C.L. Shi, D.K. Ge and W. Gao, 2001: Characteristic of climate change during wheat growing season and the orientation to develop wheat in the lower valley of the Yangtze River, Jiangsu. *J. Agr. Sci*., **17**, 193-199.

Jorgenson, M.T., C.H. Racine, J.C. Walters and T.E. Osterkamp, 2001: Permafrost degradation and ecological changes associated with a warming climate in central Alaska. *Climatic Change*, **48**, 551-571.

Juday, G.P., V. Barber, P. Duffy, H. Linderholm, S. Rupp, S. Sparrow, E. Vaganov and J. Yarie, 2005: Forests, Land Management and agriculture. *Arctic Climate Impact Assessment*. Cambridge University Press, Cambridge, 781-862.

Jung, H.S., Y. Choi, J.-H. Oh and G.H. Lim, 2002: Recent trends in temperature and precipitation over South Korea. *Int. J. Climatol*., **22**, 1327-1337.

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, Bi-annual meeting of the Meteorological Society of Japan* (in Japanese).

Kalnay, E. and M. Cai, 2003: Impact of urbanization and land-use change on climate. *Nature*, **423**, 528-531.

Kalra, N., P.K. Aggarwal, S. Chander, H. Pathak, R. Choudhary, A. Chaudhary, S. Mukesh, H.K. Rai, U.A. Soni, S. Anil, M. Jolly, U.K. Singh, A. Owrs and M.Z. Hussain, 2003: Impacts of climate change on agriculture. *Climate Change and India: Vulnerability Assessment and Adaptation*, P.R. Shukla, S.K. Sharma, N.H. Ravindranath, A. Garg and S. Bhattacharya, Eds., Orient Longman Private, Hyderbad, 193-226.

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, Bi-annual meeting of the Meteorological Society of Japan* (in Japanese).

Kelly, P.M. and W.N. Adger, 2000: Theory and Practice in Assessing Vulnerability to Climate Change and Facilitating Adaptation. *Climatic Change*, **47**, 325-352.

Khan, T.M.A., O.P. Singh and M.D. Sazedur Rahman, 2000: Recent sea level and sea surface temperature trends along the Bangladesh coast in relation to the frequency of intense cyclones. *Marine Geodesy*, **23**, 103-116.

Kirpichnikov, M., B. Reutov and A. Novikov, 2004: Scientific and technical projections of the Russian energy sector development as a factor of reduction of the negative climate change. *Proc. World Climate Change Conference, Moscow*, Y. Izrael, G. Gruza, S. Semenov and I. Nazarov, Eds., Institute of Global Climate and Ecology, Moscow, . 413-417.

Kitao M., T. Koike, H. Tobita and Y. Maruyama, 2005: Elevated CO_2 and limited nitrogen nutrition can restrict excitation energy dissipation in photosystem II of Japanese white birch (*Betula platyphylla var. japonica*) leaves. *Physiologia Plantarum*, **125**, 64-73.

Kleypas, J.A., R.W. Buddemeier, D. Archer, J.P. Gattuso, C. Langdon and B.N. Opdyke, 1999: Geochemical consequences of increased atmospheric carbon dioxide on coral reefs. *Science*, **284**, 118-120.

Knowlton, N., 2001: The future of coral reefs. *P. Natl. Acad. Sci. USA*, **98**, 5419–5425.

Knutson, T.R. and R.E. Tuleya, 2004: Impacts of CO_2 induced warming on simulated hurricane intensities and precipitation: sensitivity to the choice of climate model and convective parameterization. *J. 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., S.R. Inamdar and N.A. Sontakke, 1996: Rainfall variability over Bangladesh and Nepal: comparison and connection with features over India. *Int. J. Climatol*., **16**, 689–703.

Kudo, G., Y. Nishikawa, T. Kasagi and S. Kosuge, 2004: Does seed production of spring ephemerals decrease when spring comes early? *Ecol. Res*., **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*, **1**, 97-100.

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), (In Korean), METRI Technical Report.

Lal, M., 2001: Tropical cyclones in a warmer world. *Curr. Sci. India*, **80**, 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, 58 pp.

Lal, M., 2003: Global climate change: India's monsoon and its variability. *Journal of Environmental Studies and Policy*, **6**, 1-34.

Lal, M., 2007: Implications of climate change on agricultural productivity and food security in South Asia. *Key vulnerable regions and climate change - Identifying thresholds for impacts and adaptation in relation to Article 2 of the UNFCCC*, Springer, Dordrecht, 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. India*, **71**, 746-752.

Lal, M., K.K. Singh, L.S. Rathore, G. Srinivasan and 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., G.A. Meehl and J.M. Arblaster, 2000: Simulation of Indian summer monsoon rainfall and its intraseasonal variability. *Reg. Environ. Change*, **1**, 163-179.

Lal, M., H. Harasawa, D. Murdiyarso, W.N. Adger, S. Adhikary, M. Ando, Y. Anokhin, R.V. Cruz and Co-authors, 2001a: Asia. *Climate Change 2001: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the*

Third Assessment Report of the Intergovernmental Panel on Climate Change, J.J. McCarthy, O.F. Canziani, N.A. Leary, D.J. Dokken and K.S. White, Eds., Cambridge University Press, Cambridge, 533-590.

Lal, M., T. Nozawa, S. Emori, H. Harasawa, K. Takahashi, M. Kimoto, A. Abe-Ouchi, T. Nakajima, T. Takemura and A. Numaguti, 2001b: Future climate change: implications for Indian summer monsoon and its variability. *Curr. Sci. India*, **81**, 1196-1207.

Leont'yev, I.O., 2004: Coastal profile modelling along the Russian Arctic coast. *Coast. Eng*., **51**, 779–794.

Li, B.L. and C.H. Zhou, 2001: Climatic variation and desertification in West Sandy Land of Northeast China Plain. *Journal of Natural Resources*, **16**, 234-239.

Li, C.X, D.D. Fan, B. Deng and V. Korotaev, 2004a: The coasts of China and issues of sea level rise. *J. Coastal Res*., **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**, 495-500 (in Chinese with an English abstract).

Li, J., J.Y. Zang, Y. Saito, X.W. Xu, Y.J. Wang, E. Matsumato and Z.Y. Zhang, 2005: Several cooling events over the Hong River Delta, Vietnam during the past 5000 years. *Advances in Marine Science*, **23**, 43-53 (in Chinese with an English abstract).

Li, Q.F., F.S. Li and L. Wu, 2002: A primary analysis on climatic change and grassland degradation in Inner Mongolia. *Agricultural Research in the Arid Areas*, **20**, 98-102.

Lin, E.D., Y.L. Xu, H. Ju and W. Xiong, 2004: Possible adaptation decisions from investigating the impacts of future climate change on food and water supply in China. Paper presented at the 2nd AIACC Regional Workshop for Asia and the Pacific, 2-5 November 2004, Manila, Philippines. http://www.aiaccproject.org /meetings/Manila_04/Day2/erda_nov3.doc.

Liu, C.M. and Z.K. Chen, 2001: *Assessment on Water Resources Status and Analysis on Supply and Demand Growth in China*. China Water Conservancy and Hydropower Press, Beijing, 168pp.

Liu, C.Z., 2002: Suggestion on water resources in China corresponding with global climate change. *China Water Resources*, **2**, 36-37.

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

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

Liu, Y.B. and Y.N. Chen, 2006: Impact of population growth and land-use change on water resources and ecosystems of the arid Tarim River Basin in western China. *Int. J. Sust. Dev. World*, **13**, 295-305.

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. *P. Natl. Acad. Sci. USA*, **97**, 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. *Fish. Oceanogr*., **12**, 474-482.

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

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

Ma, Z.G. and C.B. Fu, 2003: Interannual characteristics of the surface hydrological variables over the arid and semi-arid areas of northern China. *Global Planet. Change*, **37**, 189-200.

Macintosh, D., 2005: Asia, eastern, coastal ecology. *Encyclopedia of Coastal Science*, M. Schwartz, Ed., Springer, Dordrecht, 56-67.

Malcolm, J.R., C. Liu, R.P. Neilson, L. Hansen and L. Hannah, 2006: Global warming and extinctions of endemic species from biodiversity hotspots. *Conserv. Bio*., **20**, 538–548.

Malevski-Malevich S.P., E.K. Molketin, E.D. Nadezdina and O.B. Skliarevich, 2005: Assessment of forest fire scales in the Russia under the projected climate change by 2100. *Meteorology and Hydrology*, **3**, 36-44.

Manton, M.J., P.M. Della-Marta, M.R. Haylock, K.J. Hennessy, N. Nicholls, L.E. Chambers, D.A. Collins, G. Daw and Co-authors, 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. *Journal Earth Cryosphere*, **4**, 25-34. (in Russian).

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

Matsui, T. and K. Omasa, 2002: Rice (*Oryza sativa L.*) cultivars tolerant to a high temperature at flowering: anther characteristics. *Ann. Bot.-London*, **89**, 683-687.

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. *J. Veg. Sci*., **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. *J. Veg. Sci*., **15**, 57-66.

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

May, W., 2004b: Potential future changes in the Indian summer monsoon due to greenhouse warming: analysis of mechanisms in a global time-slice experiment. *Clim. Dynam*., **22**, 389-414.

Mazda Y., M. Magi, M. Kogo and P.N. Hong, 1997: Mangroves as a costal protection from waves in the Tong King Delta, Vietnam. *Mangroves and Salt Marshes*, **1**, 127-135.

Mazda Y., M. Magi, Y. Ikeda, T. Kurokawa and T. Asano, 2006: Wave reduction in a mangrove forest dominated by *Sonneratia sp*. *Wetlands Ecology and Management*, **14**, 365-378.

McMichael, A.J., D.H. Campbell-Lendrum, C.F. Corvalan, K.L. Ebi, A.K. Githeko, J.D. Scheraga and A. Woodward, Eds., 2003: *Climate Change and Human Health - Risks and Responses*, World Health Organization, Geneva, 333 pp.

McMichael, A.J., D. Campbell-Lendrum, S. Kovats, S. Edwards, P. Wilkinson, T. Wilson, R. Nicholls and Co-authors, 2004: Global climate change. *Comparative Quantification of Health Risks: Global and Regional Burden of Disease due to Selected Major Risk Factors*, M. Ezzati, A. Lopez, A. Rodgers and C. Murray, Eds., World Health Organization, Geneva, 1543-1649.

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.V. and A.L. Revson, 2003: Remote sensing of northern regions of West Siberia. *Cryosphere of Earth*, **4**, 37-48 (in Russian).

Meshcherskaya, A.V. and V.G. Blazhevich, 1990: Catalogues of temperature-humidity characteristics with the account being taken, distribution over economic regions of the principal grain-growing zone of the USSR (1891-1983), *Gidrometeoizdat*, **3**, Leningrad.

Milliman, J.D. and R.H. Meade, 1983: World-wide delivery of river sediment to the oceans. *J. Geol*., **90**, 1-21.

Mimura, N. and H. Yokoki, 2004: Sea level changes and vulnerability of the coastal region of East Asia in response to global warming. 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.

Ministry of the Environment and Japanese Coral Reef Society, 2004: *Coral Reefs of Japan*. Ministry of the Environment, 356 pp.

Mirza, M.Q., 2002: Global warming and changes in the probability of occurrence of floods in Bangladesh and implications. *Global Environ. Chang*., **12**, 127-138.

Mirza, M.Q. and A. Dixit, 1997: Climate change and water management in the GBM Basins. *Water Nepal*, **5**, 71-100.

Mitra, A., S. Bhattacharya, R.C. Dhiman, K.K. Kumar and C. Sharma, 2004: Impact of climate change on health: a case study of malaria in India. *Climate Change and India: Vulnerability Assessment and Adaptation*, P.R. Shukla, S.K. Sharma, N.H. Ravindranath, A. Garg and S. Bhattacharya, Eds., Orient Longman Private, Hyderbad, 360-388.

MRC, 2003: *State of the Basin Report: 2003*. Mekong River Commission, Phnom Penh, 300 pp.

Murdiyarso, D., 2000: Adaptation to climatic variability and change: Asian perspectives on agriculture and food security. *Environ. Monit. Assess*., **61**, 123-131.

Murdiyarso, D. and E. Adiningsih, 2006: Climatic anomalies, Indonesian vegetation fires and terrestrial carbon emissions. *Mitigation and Adaptation Strategies for Global Change*, **12**, 101-112.

Murdiyarso, D., L. Lebel, A.N. Gintings, S.M.H. Tampubolon, A. Heil and M. Wasson, 2004: Policy responses to complex environmental problems: insights from a science-policy activity on transboundary haze from vegetation fires in

Southeast Asia. *Agr. Ecosyst. Environ.*, **104**, 47-56.

Nakagawa, H., T. Horie and T. Matsui, 2003: Effects of climate change on rice production and adaptive technologies. *Rice Science: Innovations and Impact for Livelihood*, T.W. Mew, D.S. Brar, S. Peng, D. Dawe and B. Hardy, Eds., International Rice Research Institute, Manila 635-658.

Nakićenović, N., and R. Swart, Eds., 2000: *Special Report on Emissions Scenarios. A Special Report of Working Group III of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge, 599 pp.

Natsagdorj, L., P. Gomboluudev and P. Batima, 2005: Climate change in Mongolia. *Climate Change and its Projections*, P. Batima and B. Myagmarjav, Eds., Admon publishing, Ulaanbaatar, 39-84.

Nelson, F.E., 2003: Geocryology: enhanced: (un)frozen in time. *Science*, **299**, 1673-1675.

Nerem, R.S. and G.T. Mitchum, 2001: Observations of sea level change from satellite altimetry. *Sea Level Rise: History and Consequences*, B.C. Douglas, M.S. Kearney and S.P. Leatherman, Eds., Academic, San Diego, California, 121-163.

Nguyen V.L., T.K.O. Ta and M. Tateishib, 2000: Late Holocene depositional environments and coastal evolution of the Mekong River Delta, Southern Vietnam. *J. Asian Earth Sci*., **18**, 427-439.

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 Environ. Chang*., **14**, 69-86.

Nicholls, R.J. and R.S.J. Tol, 2006: Impacts and responses to sea-level rise: a global analysis of the SRES scenarios over the 21st Century. *Philos. T. R. Soc. A*., **364**, 1073-1095.

Niou, Q.Y., 2002: *2001-2002 Report on Chinese Metropolitan Development*. Xiyuan Press, Beijing, 354 pp (in Chinese).

Nishioka, S. and H. Harasawa, Eds., 1998: *Global Warming - The Potential Impact on Japan*. Springer-Verlag, Tokyo, 244 pp.

Oda, K. and M. Ishii, 2001: Body color polymorphism in nymphs and ntaculatus (*Orthoptera*: *Tettigoniidae*) adults of a katydid, Conocephalus. *Appl. Entomol. Zool*., **36**, 345-348.

Ojima, D.S., X. Xiangming, T. Chuluun and X.S. Zhang, 1998: Asian grassland biogeochemistry: factors affecting past and future dynamics of Asian grasslands. *Asian Change in the Context of Global Climate Change*, J.N. Galloway and J.M. Melillo, Eds., *IGBP Book Series*, **3**, Cambridge University Press, Cambridge, 128-144.

Oren, R., D.S. Ellsworth, K.H. Johnsen, N. Phillips, B.E. Ewers, C. Maier, K.V.R. Schafer, H. McCarthy, G. Hendrey, S.G. McNulty and G.G. Katul, 2001: Soil fertility limits carbon sequestration by forest ecosystems in a CO_2-enriched atmosphere. *Nature*, **411**, 469-472.

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. *Arct*., *Antarct. Alp. Res*., **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 Microbiol. Ecol*., **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 and Agrometeorology Branch Technical Paper No. 2001-2, Philippine Atmospheric, Geophysical and Astronomical Services Administration, Quezon City, 55 pp.

Page, S.E., F. Siegert, J.O. Rieley, H.D.V. Boehm and A. Jaya, 2002: The amount of carbon released from peat and forest fires in Indonesia during 1997. *Nature*, **420**, 61-65.

Pan, X.L., W. Deng and D.Y. Zhang, 2003: Classification of hydrological landscapes of typical wetlands in Northeast China and their vulnerability to climate change. *Research of Environmental Sciences*, **16**, 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, International Institute of Applied Systems Analysis, 33 pp. http://www.iiasa.ac.at/Research/ECS/IEW2003/Abstracts/2003A_bhattacharya.pdf.

Parry, M.L., 2002: Scenarios for climate impacts and adaptation assessment. *Global Environ. Chang*., **12**, 149-153.

Parry, M.L., C. Rosenzweig, A. Iglesias, G. Fischer and M. Livermore, 1999: Climate change and world food security: A new assessment. *Global Environ. Chang*., **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 Environ. Chang*., **14**, 53-67.

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.

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

Patz, J.A., M.A. McGeehin, S.M. Bernard, K.L. Ebi, P.R. Epstein, A. Grambsch, D.J. Gubler, P. Reiter, I. Romieu, J.B. Rose, J.M. Samet and J. Trtanj, 2000: The potential health impacts of climate variability and change for the United States: executive summary of the report of the health sector of the U.S. National Assessment. *Environ. Health Persp*., **108**, 367-376.

Patz, J.A., D. Cambell-Lendrum, T. Holloway and J.A. Foley, 2005: Impact of regional climate on human health. *Nature*, **438**, 310-317.

Pavlov, A.V. and G.V. Ananjeva-Malkova, 2005: Small-scale mapping of contemporary air and ground temperature changes in northern Russia. *Priorities in the Earth Cryosphere Research*. Pushchino, 62-73.

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

Peng, S., J. Huang, J.E. Sheehy, R.E. Laza, R.M. Visperas, X. Zhong, G.S. Centeno, G.S. Khush and K.G. Cassman, 2004: Rice yields decline with higher night temperature from global warming. *P. Natl. Acad. Sci. USA*, **101**, 9971-9975.

Penland, S. and M.A. Kulp, 2005: Deltas. *Encyclopedia of Coastal Science*, M.L. Schwartz, Ed., Springer, Dordrecht, 362-368.

Peterson, B.J., R.M. Holmes, J.W. McClelland, C.J. Vorosmarty, R.B. Lammers, A.I. Shiklomanov, I.A. Shiklomanov and S. Rahmstorf, 2002: Increasing river discharge to the Arctic Ocean. *Science*, **298**, 137-143.

Preston, B.L., R. Suppiah, I. Macadam and J. Bathols, 2006: Climate change in the Asia/Pacific region. Report prepared for the Climate Change and Development Roundtable, Commonwealth Scientific and Industrial Research Organisation, CSIRO Publishing, Collingwood, Victoria, 89 pp.

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

Pulhin, J.M., U. Chokkalingam, R.T. Acosta, A.P. Carandang, M.Q. Natividad and R.A. Razal, 2006: Historical overview of forest rehabilitation in the Philippines. *One Century of Forest Rehabilitation in the Philippines: Approaches, Outcomes and Lessons*, U. Chokkalingam, A.P. Carandang, J.M. Pulhin, R.D. Lasco and R.J.J. Peras, Eds., CIFOR-CFNR UPLB-FMB DENR, Bogor, 6-41.

Qin, D.H., 2002: Assessment of environment change in Western China, 2nd Volume. *Prediction of Environment Change in Western China*, Science Press, Beijing, 64-161.

Qiu, G.W., Y.X. Hao and S.L. Wang, 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**, 23-28.

Rachmanin, Y.A. and Co-authors, 2004: Criteria for assessment of influence of weather and air pollution on public health. *Proc. Intl. Conf. Climate, Change and Public Health in Russia in the 21st Century*, N.F. Izmerov, B.A. Revich and E.I. Korenberg, Eds., Russian Academy of Medical Sciences - Russian Regional Committee for Cooperation with UNEP Centre for Demography and Human Ecology Russian Regional Environmental Centre Non-Governmental Organisation 'Environmental Defence', Moscow, 171-175.

Ragab, R. and C. Prudhomme, 2002: Climate change and water resources management in arid and semi-arid regions: prospective and challenges for the 21st century. *Biosystems Engineering*, **81**, 3-34.

Rahimzadeh, F., 2006: Study of precipitation variability in Iran, Research Climatology Institute, IRIMO, Tehran.

Reich, P.B., S.E. Hobbie, T. Lee, D.S. Ellsworth, J.B. West, D. Tilman, J.M.H. Knops, S. Naeem and J. Trost, 2006: Nitrogen limitation constrains sustainability of ecosystem response to CO_2. *Nature*, **440**, 922-925.

Rignot, E., A. Rivera and G. Casassa, 2003: Contribution of the Patagonia icefields of South America to sea level rise. *Science*, **302**, 434-437.

Rodo, X., M. Pascual, G. Fuchs and A.S.G. Faruque, 2002: ENSO and cholera: a nonstationary link related to climate change? *P. Natl. Acad. Sci. USA*, **99**, 12901-12906.

Romanovsky, V., M. Burgess, S. Smith, K. Yoshikawa and J. Brown, 2002: Permafrost temperature records: indicators of climate change. *EOS Transactions*, **83**, 589-594. doi:10.1029/2002EO000402.

Romanovsky, V.E., N.I. Shender, T.S. Sazonova, V.T. Balobaev, G.S. Tipenko and V.G. Rusakov, 2001: Permafrost temperatures in Alaska and East Siberia: past, present and future. *Proc. 2nd Russian Conference on Geocryology (Permafrost Science)*, Moscow, 301-314.

Rosenzweig, C., A. Iglesias, X.B. Yang, P.R. Epstein and E. Chivian, 2001: Climate change and extreme weather events: implications for food production, plant diseases and pests. *Global Change and Human Health*, **2**, 90-104.

Ruosteenoja, K., T.R. Carter, K. Jylhä and H. Tuomenvirta, 2003: Future climate in world regions: an intercomparison of model-based projections for the new IPCC emissions scenarios. The Finnish Environment 644, Finnish Environment Institute, Helsinki, 83 pp.

Rupa Kumar, K., K. Kumar, V. Prasanna, K. Kamala, N.R. Desphnade, S.K. Patwardhan and G.B. Pant, 2003: Future climate scenario. *Climate Change and India: Vulnerability Assessment and Adaptation*, P.R. Shukla, S.K. Sharma, N.H. Ravindranath, A. Garg and S. Bhattacharya, Eds., Orient Longman Private, Hyderbad, 69-127.

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.

Saito, Y., 2005: Mega-deltas in Asia: characteristics and human influences. *Mega-Deltas of Asia: Geological Evolution and Human Impact*, Z.Y. Chen, Y. Saito, S.L. Goodbred, Jr., Eds., China Ocean Press, Beijing, 1-8.

Sanlaville P. and A. Prieur, 2005: Asia, Middle East, coastal ecology and geomorphology. *Encyclopedia of Coastal Science*, M.L. Schwartz, Ed., Springer, Dordrecht, 71-83.

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. *Prog. Oceanogr.*, **47**, 279–297.

Sharkhuu, N., 2003: Recent changes in the permafrost of Mongolia. *Proc. 7th International Conference on Permafrost*, Québec, 1029-1034.

She, Z.X., 2004: Human-land interaction and socio-economic development, with special reference to the Changjiang Delta. *Proc. Xiangshan Symposium on Human-land Coupling System of River Delta Regions: Past, Present and Future*, Beijing (in Chinese).

Shein, K.A., Ed., 2006: State of the climate in 2005. *B. Am. Meteorol. Soc*., **87**, S1-S102.

Shen, X.T., Z.C. Mao and J.R. Zhu, 2003: Saltwater intrusion in the Changjiang Estuary. China Ocean Press, Beijing, 175 pp (in Chinese).

Shen, Y.P., G.X. Wang, Q.B. Wu and S.Y. Liu, 2002: The impact of future climate change on ecology and environments in the Changjiang - Yellow Rivers source region. *Journal of Glaciology and Geocryology*, **24**, 308-313.

Sheppard, C.R.C., 2003: Predicted recurrences of mass coral mortality in the Indian Ocean. *Nature*, **425**, 294 -297.

Shi, L.Q., J.F. Li, M. Ying, W.H. Li, S.L. Chen and G.A. Zhang, 2005: Advances in researches on the modern Huanghe Delta development and evolution. *Advances in Marine Science*, **23**, 96-104.

Shi, Y.F., Y.P. Shen and R.J. Hu, 2002: Preliminary study on signal, impact and foreground of climatic shift from warm-dry to warm-humid in Northwest China. *Journal of Glaciology and Geocryology*, **24**, 219-226.

Shimoda, Y., 2003: Adaptation measures for climate change and the urban heat island in Japan's built environment. *Build. Res. Inf*., **31**, 222-230.

Shoigu, S., 2004: Global climate changes and emergencies in Russia. *Proc. World Climate Change Conference,* Moscow, Y. Izrael, G. Gruza, S. Semenov and I. Nazarov, Eds., Institute of Global Climate and Ecology, Moscow, 73-85.

Short, F.T. and H.A. Neckles, 1999: The effects of global climate change on seagrasses. *Aquat. Bot*., **63**, 169-196.

Shrestha, A.B., 2004: Climate change in Nepal and its impact on Himalayan glaciers. *Presented 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.

Shrestha, A.B., C.P. Wake, J.E. Dibb and P.A. Mayewski, 2000: Precipitation fluctuations in the Nepal Himalaya and its vicinity and relationship with some large scale climatological parameters. *Int. J. Climatol*., **20**, 317-327.

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

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

Sin, S., 2000: Late Quaternary geology of the Lower Central Plain, Thailand. *J. Asian Earth Sci*., **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). *Trop. Med. Int. Health*, **9**, 364-371.

Slingo, J.M., A.J. Challinor, B.J. Hoskins and T.R. Wheeler, 2005: Food crops in a changing climate. *Phil. T. Roy. Soc. B*., **360**, 1983-1989.

Sodhi, N.S., L.P. Koh, B.W. Brook and P.K.L. Ng, 2004: Southeast Asian biodiversity: an impending disaster. *Trends Ecol. Evol*., **19**, 654-660.

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

Srinivasan, T.N., 2000: Poverty and undernutrition in South Asia. *Food Policy*, **25**, 269-282.

Stern, N., 2007: *Stern Review on the Economics of Climate Change*. Cambridge University Press. Cambridge, 692 pp.

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, 445 pp.

Sukumar, R., K.G. Saxena and A. Untawale, 2003: Climate change impacts on natural ecosystem. *Climate Change and India: Vulnerability Assessment and Adaptation*, P.R. Shukla, S.K. Sharma, N.H. Ravindranath, A. Garg and S. Bhattacharya, Eds., Orient Longman Private, Hyderbad, 266-290.

Takahashi, K., Y. Honda and S. Emori, 2007: Estimation of changes in mortality due to heat stress under changed climate. *Risk Res*., **10**, 339-354.

Takahashi, Y. and S. Kawashima, 1999: A new prediction method for the total pollen counts of *Cryprtomeria japonica* based on variation in annual summertime temperature. *Allergy*, **48**, 1217-1221.

Tan, G. and R. Shibasaki, 2003: Global estimation of crop productivity and the impacts of global warming by GIS and EPIC integration. *Ecol. Model*., **168**, 357-370.

Tan, J., L.S. Kalkstein, J. Huang, S. Lin, H. Yin and D. Shao, 2004: An operational heat/health warning system in Shanghai. *Int. J. Biometeorol*., **48**, 157-62.

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

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

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

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

Teranishi, L., Y. Kenda, T. Katoh, M. Kasuya, E. Oura and H. Taira, 2000: Possible role of climate change in the pollen scatter of Japanese cedar *Cryptomeria japonica* in Japan. *Climate Res*., **14**, 65-70.

TERI, 1996: Tata Energy Research Institute, New Delhi, Report No 93/GW/52, submitted to the Ford Foundation.

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

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

Tran, V.L., D.C. Hoang and T.T. Tran, 2005: Building of climate change scenario for Red River catchments for sustainable development and environmental protection. Preprints, *Science Workshop on Hydrometeorological Change in Vietnam and Sustainable Development*, Hanoi, Vietnam, Ministry of Natural Resource and Environment, Hanoi, 70-82.

Trenberth, K.E. and T.J. Hoar, 1997: El Niño and climate change. *Geophys. Res. Lett*., **24**, 3057-3060.

Troadec, J.P., 2000: Adaptation opportunities to climate variability and change in the exploitation and utilisation of marine living resources. *Environ. Monit. Assess*., **61**, 101-112.

Tserendash, S., B. Bolortsetseg, P. Batima, G. Sanjid, M. Erdenetuya, T. Ganbaatar and N. Manibazar, 2005: Climate change impacts on pasture. *Climate Change*

Impacts, P. Batima and B. Bayasgalan, Eds., Admon publishing, Ulaanbaatar, 59-115.

UNEP (United Nations Environment Programme), 2002: *Global Environment Outlook 3*, Earthscan, London, 426 pp.

UN-DESA-PD, 2002: World Population Prospects: World Population Prospects-2002, United Nations Department of Economic and Social Affairs - Population Division, UN, New York.

UN-ESCAP (United Nations Economic and Social Commission for Asia and the Pacific), 2006: Achieving MDGs in Asia: a case for more aid? UN-ESCAP, New York, 37 pp.

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

Vermaat, J. and U. Thampanya, 2006: Mangroves mitigate tsunami damage: a further response. *Estuar. Coast. Shelf S.*, **69**, 1-3.

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**, 213-233.

Vorobyov, Y., 2004: Climate change and disasters in Russia. *Proc. World Climate Change Conference, Moscow*, Y. Izrael, G. Gruza, S. Semenov and I. Nazarov, Eds., Institute of Global Climate and Ecology, Moscow, 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 International Symposium on Plant Responses to Air Pollution and Global Changes*, Tsukuba, 215.

Walsh, K.J.E., 2004: Tropical cyclones and climate change: unresolved issues. *Climate Res.*, **27**, 77-84.

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

Wang, G.Z., 2005: Global sea-level change and coral reefs of China. *Journal of Palaeogeography*, **7**, 483-492 (in Chinese with an English abstract).

Wang, M., Y. Li and S. Pang, 2004a: Influences of climate change on sustainable development of the hinterland of Qinghai-Tibet Plateau, Chinese Journal of *Population, Resources and Environment*, **14**, 92-95.

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

Wang, X., F. Chen and Z. Dong, 2006: The relative role of climatic and human factors in desertification in semiarid China. *Global Environ. Chang.*, **16**, 48-57.

Wang, X.C. and P.K. Jin, 2006: Water shortage and needs for wastewater re-use in the north China. *Water Sci. Technol.*, **53**, 35-44.

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

Wang, Z.W. and P.M. Zhai, 2003: Climate change in drought over northern China during 1950–2000. *Acta Geographica Sinica*, **58**, 61–68 (in Chinese).

Wassmann, R., N.X. Hien, C.T. Hoanh and T.P. Tuong, 2004: Sea level rise affecting the Vietnamese Mekong Delta: water elevation in the flood season and implications for rice production. *Climatic Change*, **66**, 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.

Wijeratne, M.A., 1996: Vulnerability of Sri Lanka tea production to global climate change. *Water Air Soil Poll.*, **92**, 87-94.

Wilkinson, C., Ed., 2000: *Status of Coral Reefs of the World: 2000*. Australian Institute of Marine Science, Townsville, 363 pp.

Wilkinson, C., Ed., 2002: *Status of Coral Reefs of the World: 2002*. Australian Institute of Marine Science, Townsville, 378 pp.

Wilkinson, C., Ed., 2004: *Status of Coral Reefs of the World: 2004, Volume 1*. Australian Institute of Marine Science, Townsville, 302 pp.

Wilkinson, P., D.H. Campbell-Lendrum and C.L. Bartlett, 2003: Monitoring the health effects of climate change. *Climate Change and Human Health - Risks and Responses*, A.J. McMichael, D.H. Campbell-Lendrum, C.F. Corvalan, K.L. Ebi, A.K. Githeko, J.D. Scheraga, A. Woodward, Eds., World Health Organization, Geneva, 204-219.

Wolanski, E., 2007: Protective functions of coastal forests and trees against natural hazards. Coastal protection in the aftermath of the Indian Ocean tsunami: what role for forests and trees? *Proc. FAO Regional Technical Workshop, Khao Lak, Thailand*, 28-31 August 2006. FAO, Bangkok.

Woodroffe, C.D., R.J. Nicholls, Y. Saito, Z. Chen and S.L. Goodbred, 2006: Landscape variability and the response of Asian megadeltas to environmental change. *Global Change and Integrated Coastal Management: The Asia-Pacific Region*, N. Harvey, Ed., Springer, 277-314.

Woodworth, P.L., J.M. Gregory and R.J. Nicholls, 2004: Long term sea level changes and their impacts. *The Sea*, A. Robinson and K. Brink, Eds., Harvard Univ. Press, Cambridge, Massachusetts, 717-752.

World Bank, 2002: World Development Indicators 2002, CD-ROM, Washington, District of Columbia.

World Bank, 2004: Modelled Observations on Development Scenarios in the Lower Mekong Basin, Prepared for the World Bank with cooperation of the Mekong Regional Water Resources Assistance Strategy, World Bank, Vientiane, 142 pp. http://www.catchment.crc.org.au/cgi-bin/WebObjects/toolkit.woa/1/wa/publicationDetail?wosid=5Ir4xCtBn8NbvG2w3KZWrw&publicationID=1000068.

World Bank, 2005: World Development Indicators, World Bank, Washington, District of Columbia. http://web.worldbank.org/WBSITE/EXTERNAL/DATASTATISTICS/0,,contentMDK:20523710~hlPK:1365919~menuPK:64133159~pagePK:64133150~piPK:64133175~theSitePK:239419,00.html

World Tourism Organization, 2003: Climate change and tourism. *Proc. 1st International Conference on Climate Change and Tourism*, Djerba, Tunisia, World Tourism Organization, 55 pp.

WRI (World Resource Institute), 2003: *World Resources 2002-2004*. World Resources Institute, Washington, District of Columbia, 315 pp.

Wu, Q.B., X. Li and W.J. Li, 2001: The response model of permafrost along the Qinghai – Tibetan Highway under climate change. *Journal of Glaciology and Cryology*, **23**, 1-6.

Wu, S.Y., B. Yarnal and A. Fisher, 2002: Vulnerability of coastal communities to sea-level rise: a case study of Cape May County, New Jersey, USA. *Climate Res.*, **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**, 771-775.

WWF (World Wildlife Fund), 2005: An overview of glaciers, glacier retreat, and subsequent impacts in Nepal, India and China. World Wildlife Fund, Nepal Programme, 79 pp.

Xu, C.X., 2003: *China National Offshore and Coastal Wetlands Conservation Action Plan*. China Ocean Press, Beijing, 116 pp (in Chinese).

Xue, X.Z., H.S. Hong and A.T. Charles, 2004: Cumulative environmental impacts and integrated coastal management: the case of Xiamen, China. *J. Environ. Manage.*, **71**, 271-283.

Yamano, H. and M. Tamura, 2004: Detection limits of coral reef bleaching by satellite remote sensing: simulation and data analysis. *Remote Sens. Environ.*, **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**, 23-30 (in Chinese with an English abstract).

Yao, T.D., X.D. Liu, N.L. Wang and Y.F. Shi, 2000: Amplitude of climatic changes in Qinghai-Tibetan Plateau. *Chinese Sci. Bull.*, **45**, 98-106.

Yasukevich, V.V. and S.M. Semenov, 2004: Simulation of climate-induced changes in natural habitats of malaria in Russia and neighboring countries, *Proc. Intl. Conf. on Climate Change and Public Health in Russia*, N.F. Izmerov, B.A. Revich and E.I. Korenberg, Eds., Russian Academy of Sciences, Moscow, 147-153.

Yin, Y.Y., Q.L. Miao and G.S. Tian, 2003: *Climate Change and Regional Sustainable Development*. Science Press, Beijing and New York, 224 pp.

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

Yoshino, M., 2000: Problems in climatology of dust storm and its relation to human activities in Northwest China. *Journal of Arid Land Studies*, **10**, 171-181.

Yoshino, M., 2002: Kosa (Asian dust) related to Asian Monsoon System. *Korean Journal of Atmospheric Sciences*, **5**, S93-S100.

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**, 329-335.

Zafar, A., 2005: Training and capacity building for managing our mangroves resources- UNU's role to meet regional challenges. Environment and Sustainable Development Programme, Tokyo, Japan, Technical Notes of United Nations University, 5 pp. http://www.inweh.unu.edu/inweh/Training/UNU_Man groves_course.pdf.

Zalikhanov, M., 2004: Climate change and sustainable development in the Russian Federation. *Proc. World Climate Change Conference, Moscow, September 29-October 2003*, Yu. Izrael, G. Gruza, S. Semenov and I. Nazarov, Eds., Institute of Global Climate and Ecology, Moscow, 466-477.

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**, 313-319.

Zhai, P. and X. Pan, 2003: Trends in temperature extremes during 1951-1999 in China. *Geophys. Res. Lett.*, **30**, 1913, doi:10.1029/2003GL018004.

Zhai, P.M., 2004: Climate change and meteorological disasters. *Science and Technology Reviews*, **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**, 1-9.

Zhang, Q. and G. Guo, 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, Y., W. Chen and J. Cihlar, 2003: A process-based model for quantifying the impact of climate change on permafrost thermal regimes. *J. Geophys. Res.*, **108**, 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 Planet. Change*, **43**, 19-31.

Zhou, Y.H., 2003: Characteristics of weather and climate during drought periods in South China. *Journal of Applied Meteorological Science*, **14**, S118-S125.

Ziska, L.H., 2003: Evaluation of the growth response of six invasive species to past, present and future atmospheric carbon dioxide. *J. Exp. Bot.*, **54**, 395-404.

Zolotov, P.A. and Caliberny, 2004: Human physiological functions and public health Ultra-Continental Climate. *Proc. Intl. Conf. on Climate Change and Public Health in Russia*, N.F. Izmerov, B.A. Revich and E.I. Korenberg, Eds., Russian Academy of Sciences, Moscow, 212-222.