

Asia

Coordinating Lead Authors:

Yasuaki Hijioka (Japan), Erda Lin (China), Joy Jacqueline Pereira (Malaysia)

Lead Authors:

Richard T. Corlett (China), Xuefeng Cui (China), Gregory Inсарov (Russian Federation), Rodel Lasco (Philippines), Elisabet Lindgren (Sweden), Akhilesh Surjan (India)

Contributing Authors:

Elena M. Aizen (USA), Vladimir B. Aizen (USA), Rawshan Ara Begum (Bangladesh), Kenshi Baba (Japan), Monalisa Chatterjee (USA/India), J. Graham Cogley (Canada), Noah Diffenbaugh (USA), Li Ding (Singapore), Qingxian Gao (China), Matthias Garschagen (Germany), Masahiro Hashizume (Japan), Manmohan Kapshe (India), Andrey G. Kostianoy (Russia), Kathleen McInnes (Australia), Sreeja Nair (India), S.V.R.K. Prabhakar (India), Yoshiki Saito (Japan), Andreas Schaffer (Singapore), Rajib Shaw (Japan), Dáithí Stone (Canada/South Africa /USA), Reiner Wassman (Philippines), Thomas J. Wilbanks (USA), Shaohong Wu (China)

Review Editors:

Rosa Perez (Philippines), Kazuhiko Takeuchi (Japan)

Volunteer Chapter Scientists:

Yuko Onishi (Japan), Wen Wang (China)

This chapter should be cited as:

Hijioka, Y., E. Lin, J.J. Pereira, R.T. Corlett, X. Cui, G.E. Inсарov, R.D. Lasco, E. Lindgren, and A. Surjan, 2014: Asia. In: *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Barros, V.R., C.B. Field, D.J. Dokken, M.D. Mastrandrea, K.J. Mach, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1327-1370.

Table of Contents

- Executive Summary 1330**

- 24.1. Introduction 1332**

- 24.2. Major Conclusions from Previous Assessments 1332**
 - Box 24-1. What’s New on Asia in AR5? 1333**

- 24.3. Observed and Projected Climate Change 1333**
 - 24.3.1. Observed Climate Change 1333
 - 24.3.1.1. Temperature 1333
 - 24.3.1.2. Precipitation and Monsoons 1333
 - 24.3.1.3. Tropical and Extratropical Cyclones 1333
 - 24.3.1.4. Surface Wind Speeds 1334
 - 24.3.1.5. Oceans 1334
 - 24.3.2. Projected Climate Change 1334
 - 24.3.2.1. Tropical and Extratropical Cyclones 1334
 - 24.3.2.2. Monsoons 1334
 - 24.3.2.3. Oceans 1334

- 24.4. Observed and Projected Impacts, Vulnerabilities, and Adaptation 1334**
 - 24.4.1. Freshwater Resources 1334
 - 24.4.1.1. Sub-regional Diversity 1334
 - 24.4.1.2. Observed Impacts 1337
 - 24.4.1.3. Projected Impacts 1337
 - 24.4.1.4. Vulnerabilities to Key Drivers 1338
 - 24.4.1.5. Adaptation Options 1338
 - 24.4.2. Terrestrial and Inland Water Systems 1339
 - 24.4.2.1. Sub-regional Diversity 1339
 - 24.4.2.2. Observed Impacts 1339
 - 24.4.2.3. Projected Impacts 1340
 - 24.4.2.4. Vulnerabilities to Key Drivers 1341
 - 24.4.2.5. Adaptation Options 1341
 - 24.4.3. Coastal Systems and Low-Lying Areas 1341
 - 24.4.3.1. Sub-regional Diversity 1341
 - 24.4.3.2. Observed Impacts 1342
 - 24.4.3.3. Projected Impacts 1342
 - 24.4.3.4. Vulnerabilities to Key Drivers 1342
 - 24.4.3.5. Adaptation Options 1343
 - 24.4.4. Food Production Systems and Food Security 1343
 - 24.4.4.1. Sub-regional Diversity 1343
 - 24.4.4.2. Observed Impacts 1343

24.4.4.3. Projected Impacts	1343
24.4.4.4. Vulnerabilities to Key Drivers	1345
24.4.4.5. Adaptation Options	1345
24.4.5. Human Settlements, Industry, and Infrastructure	1346
24.4.5.1. Sub-regional Diversity	1346
24.4.5.2. Observed Impacts	1346
24.4.5.3. Projected Impacts	1346
24.4.5.4. Vulnerabilities to Key Drivers	1347
24.4.5.5. Adaptation Options	1347
24.4.6. Human Health, Security, Livelihoods, and Poverty	1348
24.4.6.1. Sub-regional Diversity	1348
24.4.6.2. Observed Impacts	1348
24.4.6.3. Projected Impacts	1349
24.4.6.4. Vulnerabilities to Key Drivers	1350
24.4.6.5. Adaptation Options	1350
24.4.7. Valuation of Impacts and Adaptation	1350
24.5. Adaptation and Managing Risks	1351
24.5.1. Conservation of Natural Resources	1351
24.5.2. Flood Risks and Coastal Inundation	1351
24.5.3. Economic Growth and Equitable Development	1351
24.5.4. Mainstreaming and Institutional Barriers	1351
24.5.5. Role of Higher Education in Adaptation and Risk Management	1352
24.6. Adaptation and Mitigation Interactions	1352
24.7. Intra-regional and Inter-regional Issues	1353
24.7.1. Transboundary Pollution	1353
24.7.2. Trade and Economy	1353
24.7.3. Migration and Population Displacement	1353
24.8. Research and Data Gaps	1353
24.9. Case Studies	1355
24.9.1. Transboundary Adaptation Planning and Management —Lower Mekong River Basin	1355
24.9.2. Glaciers of Central Asia	1355
References	1356
Frequently Asked Questions	
24.1: What will the projected impact of future climate change be on freshwater resources in Asia?	1338
24.2: How will climate change affect food production and food security in Asia?	1344
24.3: Who is most at risk from climate change in Asia?	1347

Executive Summary

Warming trends and increasing temperature extremes have been observed across most of the Asian region over the past century (*high confidence*). {24.3} Increasing numbers of warm days and decreasing numbers of cold days have been observed, with the warming trend continuing into the new millennium. Precipitation trends including extremes are characterized by strong variability, with both increasing and decreasing trends observed in different parts and seasons of Asia.

Water scarcity is expected to be a major challenge for most of the region as a result of increased water demand and lack of good management (*medium confidence*). {24.4.3} Water resources are important in Asia because of the massive population and vary among regions and seasons. However, there is *low confidence* in future precipitation projections at a sub-regional scale and thus in future freshwater availability in most parts of Asia. Population growth and increasing demand arising from higher standards of living could worsen water security in many parts in Asia and affect many people in the future. Integrated water management strategies could help adapt to climate change, including developing water-saving technologies, increasing water productivity, and water reuse.

The impacts of climate change on food production and food security in Asia will vary by region, with many regions to experience a decline in productivity (*medium confidence*). {24.4.4} This is evident in the case of rice production. Most models, using a range of General Circulation Models (GCMs) and *Special Report on Emission Scenarios* (SRES) scenarios, show that higher temperatures will lead to lower rice yields as a result of shorter growing periods. There are a number of regions that are already near the heat stress limits for rice. However, carbon dioxide (CO₂) fertilization may at least in part offset yield losses in rice and other crops. In Central Asia, some areas could be winners (cereal production in northern and eastern Kazakhstan could benefit from the longer growing season, warmer winters, and slight increase in winter precipitation), while others could be losers (western Turkmenistan and Uzbekistan, where frequent droughts could negatively affect cotton production, increase water demand for irrigation, and exacerbate desertification). In the Indo-Gangetic Plains of South Asia there could be a decrease of about 50% in the most favorable and high-yielding wheat area as a result of heat stress at 2 times CO₂. Sea level rise will inundate low-lying areas and will especially affect rice growing regions. Many potential adaptation strategies are being practiced and proposed but research studies on their effectiveness are still few.

Terrestrial systems in many parts of Asia have responded to recent climate change with shifts in the phenologies, growth rates, and the distributions of plant species, and with permafrost degradation, and the projected changes in climate during the 21st century will increase these impacts (*high confidence*). {24.4.2} Boreal trees will *likely* invade treeless arctic vegetation, while evergreen conifers will *likely* invade deciduous larch forest. Large changes may also occur in arid and semiarid areas, but uncertainties in precipitation projections make these more difficult to predict. The rates of vegetation change in the more densely populated parts of Asia may be reduced by the impact of habitat fragmentation on seed dispersal, while the impacts of projected climate changes on the vegetation of the lowland tropics are currently poorly understood. Changes in animal distributions have also been projected, in response to both direct impacts of climate change and indirect impacts through changes in the availability of suitable habitats.

Coastal and marine systems in Asia are under increasing stress from both climatic and non-climatic drivers (*high confidence*). {24.4.3} It is *likely* that mean sea level rise will contribute to upward trends in extreme coastal high water levels. {WGI AR5 3.7.6} In the Asian Arctic, rising sea levels are expected to interact with projected changes in permafrost and the length of the ice-free season to cause increased rates of coastal erosion (*medium evidence, high agreement*). Mangroves, salt marshes, and seagrass beds may decline unless they can move inland, while coastal freshwater swamps and marshes will be vulnerable to saltwater intrusion with rising sea levels. Widespread damage to coral reefs correlated with episodes of high sea surface temperature has been reported in recent decades and there is *high confidence* that damage to reefs will increase during the 21st century as a result of both warming and ocean acidification. Marine biodiversity is expected to increase at temperate latitudes as warmwater species expand their ranges northward (*high confidence*), but may decrease in the tropics if thermal tolerance limits are exceeded (*medium confidence*).

Multiple stresses caused by rapid urbanization, industrialization, and economic development will be compounded by climate change (*high confidence*). {24.4-7} Climate change is expected to adversely affect the sustainable development capabilities of most Asian developing countries by aggravating pressures on natural resources and the environment. Development of sustainable cities in Asia with fewer fossil fuel-driven vehicles and with more trees and greenery would have a number of co-benefits, including improved public health.

Extreme climate events will have an increasing impact on human health, security, livelihoods, and poverty, with the type and magnitude of impact varying across Asia (*high confidence*). {24.4.6} More frequent and intense heat waves in Asia will increase mortality and morbidity in vulnerable groups. Increases in heavy rain and temperature will increase the risk of diarrheal diseases, dengue fever, and malaria. Increases in floods and droughts will exacerbate rural poverty in parts of Asia as a result of negative impacts on the rice crop and resulting increases in food prices and the cost of living.

Studies of observed climate changes and their impacts are still inadequate for many areas, particularly in North, Central, and West Asia (*high confidence*). {24.8} Improved projections for precipitation, and thus water supply, are most urgently needed. Understanding of climate change impacts on ecosystems in Asia is currently limited by the incompleteness and inaccessibility of biodiversity information. Major research gaps in the tropics include the temperature dependence of carbon fixation by tropical trees and the thermal tolerances and acclimation capacities of both plants and animals. Interactions between climate change and the direct impacts of rising CO₂ on crops and natural ecosystems are also currently poorly understood. More research is needed on impacts, vulnerability, and adaptation in urban settlements, especially cities with populations of less than 500,000. More generally, there is a need to develop low-cost adaptation measures appropriate to the least developed parts of the region.

24.1. Introduction

Asia is defined here as the land and territories of 51 countries/regions (see Figure 24-1). It can be broadly divided into six subregions based on geographical position and coastal peripheries. These are, in alphabetical order, Central Asia (5 countries), East Asia (7 countries/regions), North Asia (2 countries), South Asia (8 countries), Southeast Asia (12 countries), and West Asia (17 countries). The population of Asia was reported to be about 4299 million in 2013, which is about 60% of the world population (UN DESA Population Division, 2013). Population density was reportedly about 134 per square kilometer in 2012 (PRB, 2012). The highest life expectancy at birth is 84 (Japan) and the lowest is 50 (Afghanistan) (CIA, 2013). The gross domestic product (GDP) per capita ranged from US\$620 (Afghanistan for 2011) to US\$51,709 (Singapore for 2012) (World Bank, 2013).

24.2. Major Conclusions from Previous Assessments

Major highlights from previous assessments for Asia include:

- Warming trends, including higher extremes, are strongest over the continental interiors of Asia, and warming in the period 1979 onward was strongest over China in winter, and northern and eastern Asia in spring and autumn (WGI AR4 Section 3.2.2.7; SREX Section 3.3.1).
- From 1900 to 2005, precipitation increased significantly in northern and central Asia but declined in parts of southern Asia (WGI AR4 SPM).
- Future climate change is *likely* to affect water resource scarcity with enhanced climate variability and more rapid melting of glaciers (WGII AR4 Section 10.4.2).
- Increased risk of extinction for many plant and animal species in Asia is *likely* as a result of the synergistic effects of climate change and habitat fragmentation (WGII AR4 Section 10.4.4).
- Projected sea level rise is *very likely* to result in significant losses of coastal ecosystems (WGII AR4 Sections 10.4.3.2, 10.6.1).
- There will be regional differences within Asia in the impacts of climate change on food production (WGII AR4 Section 10.4.1.1).
- Due to projected sea level rise, a million or so people along the coasts of South and Southeast Asia will likely be at risk from flooding (*high confidence*; WGII AR4 Section 10.4.3.1).
- 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 urbanization, industrialization, and economic development (WGII AR4 Section 10.7).
- Vulnerabilities of industry, infrastructure, settlements, and society to climate change are generally greater in certain high-risk locations, particularly coastal and riverine areas (WGII AR4 Sections 7.3-5).

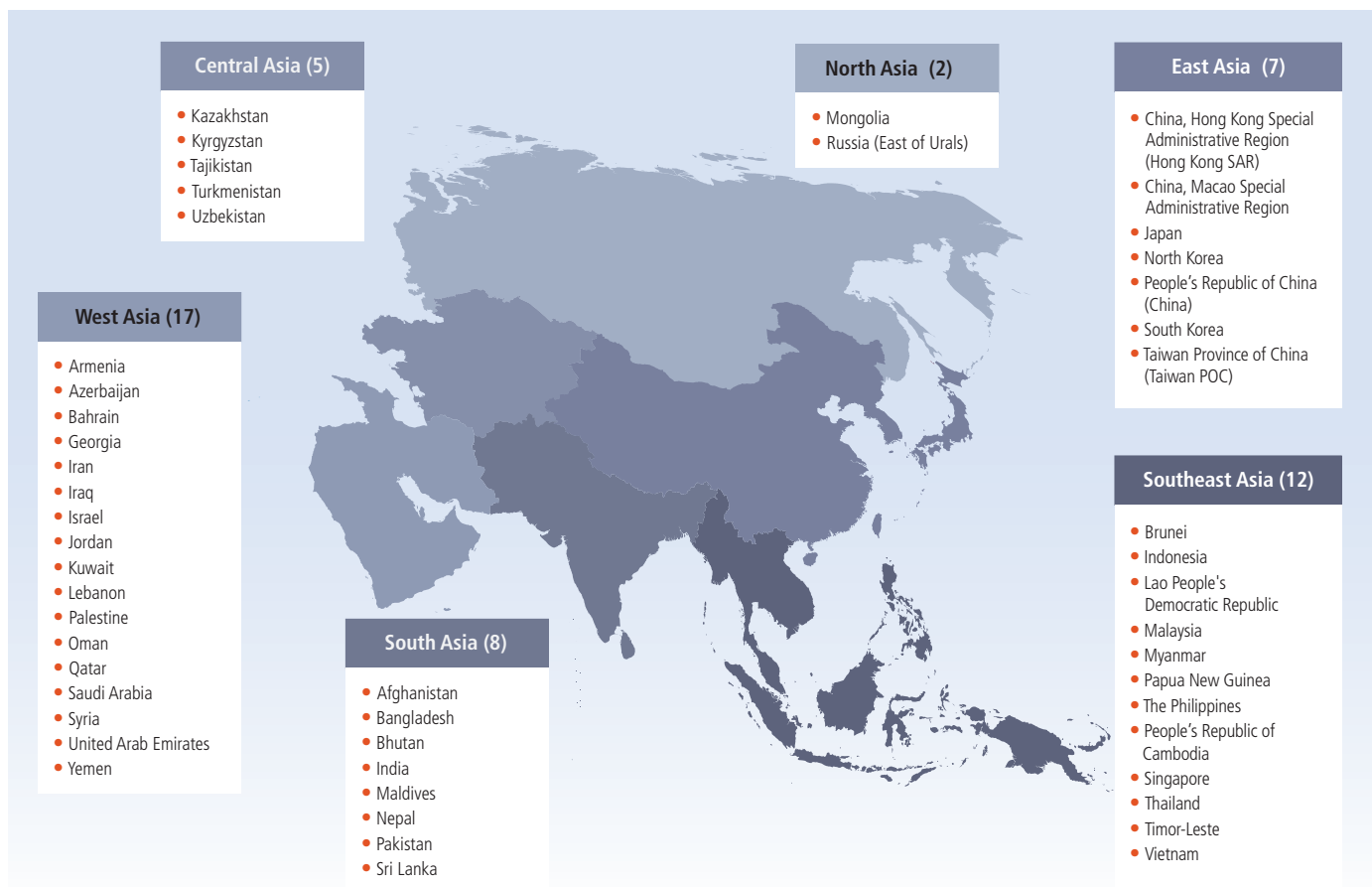


Figure 24-1 | The land and territories of 51 countries/regions in Asia. Maps contained in this report are only for the purpose of geographic information reference.

Box 24-1 | What's New on Asia in AR5?

- There is improved country coverage on observed and future impacts of climate change.
- There is an increase in the number of studies reflecting advances in research tools (e.g., more use of remote sensing and modeling of impacts), with an evaluation of detection and attribution where feasible.
- More conclusions have confidence statements, while confidence levels have changed in both directions since AR4.
- Expanded coverage of issues—for example, discussion of the Himalayas has been expanded to cover observed and projected impacts (Box 3-2), including those on tourism (see Section 10.6.2); livelihood assets such as water and food (Sections 9.3.3.1, 13.3.1.1, 18.5.3, 19.6.3); poverty (Section 13.3.2.3); culture (Section 12.3.2); flood risks (Sections 18.3.1.1, 24.2.1); health risks (Section 24.4.6.2); and ecosystems (Section 24.4.2.2).

24.3. Observed and Projected Climate Change

24.3.1. Observed Climate Change

24.3.1.1. Temperature

It is *very likely* that mean annual temperature has increased over the past century over most of the Asia region, but there are areas of the interior and at high latitudes where the monitoring coverage is insufficient for the assessment of trends (see WGI AR5 Chapter 2; Figure 24-2). New analyses continue to support the Fourth Assessment Report (AR4) and IPCC *Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation* (SREX) conclusions that it is *likely* that the numbers of cold days and nights have decreased and the numbers of warm days and nights have increased across most of Asia since about 1950, and heat wave frequency has increased since the middle of the 20th century in large parts of Asia (see WGI AR5 Section 2.6.1).

As a part of the polar amplification, large warming trends (>2°C per 50 years) in the second half of the 20th century were observed in the northern Asian sector (see WGI AR5 Section 14.8.8). Over the period 1901–2009, the warming trend was particularly strong in the cold season between November and March, with an increase of 2.4°C in the mid-latitude semiarid area of Asia (see WGI AR5 Section 14.8.8). Increasing annual mean temperature trends at the country scale in East and South Asia have been observed during the 20th century (Table SM24-1). In West Asia, upward temperature trends are notable and robust in recent

decades (WGI AR5 Section 14.8.10). Across Southeast Asia, temperature has been increasing at a rate of 0.14°C to 0.20°C per decade since the 1960s, coupled with a rising number of hot days and warm nights, and a decline in cooler weather (see WGI AR5 Section 14.8.12).

24.3.1.2. Precipitation and Monsoons

Most areas of the Asian region lack sufficient observational records to draw conclusions about trends in annual precipitation over the past century (see WGI AR5 Chapter 2; Figure 24-2; Table SM24-2). Precipitation trends, including extremes, are characterized by strong variability, with both increasing and decreasing trends observed in different parts and seasons of Asia (see WGI AR5 Chapter 14; Table SM24-2). In northern Asia, the observations indicate some increasing trends of heavy precipitation events, but in central Asia, no spatially coherent trends were found (see WGI AR5 Section 14.8.8). Both the East Asian summer and winter monsoon circulations have experienced an inter-decadal scale weakening after the 1970s, due to natural variability of the coupled climate system, leading to enhanced mean and extreme precipitation along the Yangtze River valley (30°N), but deficient mean precipitation in North China in summer (see WGI AR5 Section 14.8.9). A weakening of the East Asian summer monsoon since the 1920s was also found in sea level pressure gradients (*low confidence*; see WGI AR5 Section 2.7.4). In West Asia, a weak but non-significant downward trend in mean precipitation was observed in recent decades, although with an increase in intense weather events (see WGI AR5 Section 14.8.10). In South Asia, seasonal mean rainfall shows inter-decadal variability, noticeably a declining trend with more frequent deficit monsoons under regional inhomogeneities (see WGI AR5 Section 14.8.11). Over India, the increase in the number of monsoon break days and the decline in the number of monsoon depressions are consistent with the overall decrease in seasonal mean rainfall (see WGI AR5 Section 14.8.11). But an increase in extreme rainfall events occurred at the expense of weaker rainfall events over the central Indian region and in many other areas (see WGI AR5 Section 14.2.2.1). In South Asia, the frequency of heavy precipitation events is increasing, while light rain events are decreasing (see WGI AR5 Section 14.8.11). In Southeast Asia, annual total wet-day rainfall has increased by 22 mm per decade, while rainfall from extreme rain days has increased by 10 mm per decade, but climate variability and trends differ vastly across the region and between seasons (see WGI AR5 Sections 14.4.12, 14.8.12). In Southeast Asia, between 1955 and 2005 the ratio of rainfall in the wet to the dry seasons increased. While an increasing frequency of extreme events has been reported in the northern parts of Southeast Asia, decreasing trends in such events are reported in Myanmar (see WGI AR5 Section 14.4.12). In Peninsular Malaya during the southwest monsoon season, total rainfall and the frequency of wet days decreased, but rainfall intensity increased in much of the region. On the other hand, during the northeast monsoon, total rainfall, the frequency of extreme rainfall events, and rainfall intensity all increased over the peninsula (see WGI AR5 Section 14.4.12).

24.3.1.3. Tropical and Extratropical Cyclones

Significant trends in tropical cyclones making landfall are not found on shorter timescales. Time series of cyclone indices show weak upward

trends in the western North Pacific since the late 1970s, but interpretation of longer term trends is constrained by data quality concerns (see WGI AR5 Section 2.6.3). A decrease in extratropical cyclone activity and intensity over the last 50 years has been reported for northern Eurasia (60°N to 40°N), including lower latitudes in East Asia (see WGI AR5 Section 2.6.4).

24.3.1.4. Surface Wind Speeds

Over land in China, including the Tibetan region, a weakening of the seasonal and annual mean winds, as well as the maximums, is reported from around the 1960s or 1970s to the early 2000s (*low confidence*; see WGI AR5 Section 2.7.2).

24.3.1.5. Oceans

A warming maximum is observed at 25°N to 65°N with signals extending to 700 m depth and is consistent with poleward displacement of the mean temperature field (WGI AR5 Section 3.2.2). The pH measurements between 1983 and 2008 in the western North Pacific showed a $-0.0018 \pm 0.0002 \text{ yr}^{-1}$ decline in winter and $-0.0013 \pm 0.0005 \text{ yr}^{-1}$ decline in summer (see WGI AR5 Section 3.8.2). Over the period 1993–2010, large rates of sea level rise in the western tropical Pacific were reported, corresponding to an increase in the strength of the trade winds in the central and eastern tropical Pacific (see WGI AR5 Section 13.6.1). Spatial variation in trends in Asian regional sea level may also be specific to a particular sea or ocean basin. For example, a rise of $5.4 \pm 0.3 \text{ mm yr}^{-1}$ in the Sea of Japan from 1993 to 2001 is nearly two times the global mean sea level (GMSL) trend, with more than 80% of this rise being thermosteric, and regional changes of sea level in the Indian Ocean that have emerged since the 1960s are driven by changing surface winds associated with a combined enhancement of Hadley and Walker cells (see WGI AR5 Section 13.6.1).

24.3.2. Projected Climate Change

The AR4 assessed that warming is *very likely* in the 21st century (Christensen et al., 2007), and that assessment still holds for all land areas of Asia in the mid- and late-21st century, based on the Coupled Model Intercomparison Project Phase 5 (CMIP5) simulations under all four Representative Concentration Pathway (RCP) scenarios (Figures 24-2, SM24-1; Table SM24-3). Ensemble-mean changes in mean annual temperature exceed 2°C above the late-20th-century baseline over most land areas in the mid-21st century under RCP8.5, and range from greater than 3°C over South and Southeast Asia to greater than 6°C over high latitudes in the late-21st century. The ensemble-mean changes are less than 2°C above the late-20th-century baseline in both the mid- and late-21st century under RCP2.6, with the exception of changes between 2°C and 3°C over the highest latitudes.

Projections of future annual precipitation change are qualitatively similar to those assessed in the AR4 (Christensen et al., 2007; see Figure 24-2). Precipitation increases are *very likely* at higher latitudes by the mid-21st century under the RCP8.5 scenario, and over eastern and southern

areas by the late-21st century. Under the RCP2.6 scenario, increases are *likely* at high latitudes by the mid-21st century, while it is *likely* that changes at low latitudes will not substantially exceed natural variability.

24.3.2.1. Tropical and Extratropical Cyclones

The future influence of climate change on tropical cyclones is *likely* to vary by region, but there is *low confidence* in region-specific projections of frequency and intensity. However, better process understanding and model agreement in specific regions indicate that precipitation will *likely* be more extreme near the centers of tropical cyclones making landfall in West, East, South, and Southeast Asia (see WGI AR5 Sections 14.6, 14.8.9-12). There is *medium confidence* that a projected poleward shift in the North Pacific storm track of extratropical cyclones is *more likely than not*. There is *low confidence* in the magnitude of regional storm track changes and the impact of such changes on regional surface climate (see WGI AR5 Section 14.6).

24.3.2.2. Monsoons

Future increases in precipitation extremes related to the monsoon are *very likely* in East, South, and Southeast Asia (see WGI AR5 Sections 14.2.1, 14.8.9, 14.8.11-12). More than 85% of CMIP5 models show an increase in mean precipitation in the East Asian summer monsoons, while more than 95% of models project an increase in heavy precipitation events (see WGI AR5 Section 14.2.2, Figure 14.4). All models and all scenarios project an increase in both the mean and extreme precipitation in the Indian summer monsoon (see WGI AR5 Section 14.2.2 and Southern Asia (SAS) in Figure 14.4). In these two regions, the interannual standard deviation of seasonal mean precipitation also increases (see WGI AR5 Section 14.2.2).

24.3.2.3. Oceans

The ocean in subtropical and tropical regions will warm in all RCP scenarios and will show the strongest warming signal at the surface (WGI AR5 Section 12.4.7, Figure 12.12). Negligible change or a decrease in mean significant wave heights are projected for the trade and monsoon wind regions of the Indian Ocean (see WGI AR5 Section 13.7.3).

24.4. Observed and Projected Impacts, Vulnerabilities, and Adaptation

Key observed and projected climate change impacts are summarized in Tables 24-1, SM24-4, and SM24-5 (based on Sections 24.4.1-6).

24.4.1. Freshwater Resources

24.4.1.1. Sub-regional Diversity

Freshwater resources are very important in Asia because of the massive population and heavy economic dependence on agriculture, but water

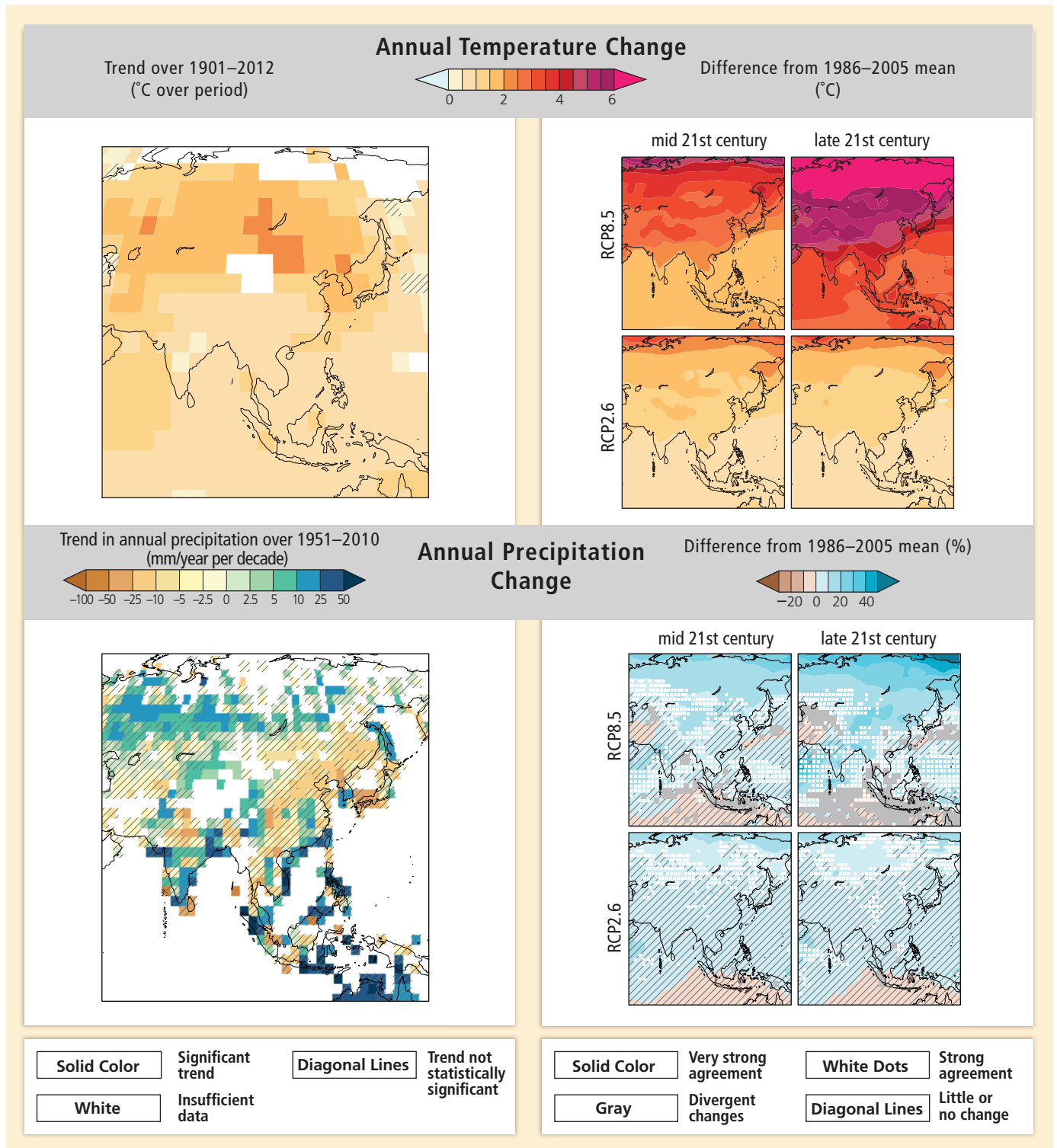


Figure 24-2 | Observed and projected changes in annual average temperature and precipitation in Asia. (Top panel, left) Map of observed annual average temperature change from 1901–2012, derived from a linear trend. [WGI AR5 Figures SPM.1 and 2.21] (Bottom panel, left) Map of observed annual precipitation change from 1951–2010, derived from a linear trend. [WGI AR5 Figures SPM.2 and 2.29] For observed temperature and precipitation, trends have been calculated where sufficient data permit a robust estimate (i.e., only for grid boxes with greater than 70% complete records and more than 20% data availability in the first and last 10% of the time period). Other areas are white. Solid colors indicate areas where trends are significant at the 10% level. Diagonal lines indicate areas where trends are not significant. (Top and bottom panel, right) CMIP5 multi-model mean projections of annual average temperature changes and average percent changes in annual mean precipitation for 2046–2065 and 2081–2100 under RCP2.6 and 8.5, relative to 1986–2005. Solid colors indicate areas with very strong agreement, where the multi-model mean change is greater than twice the baseline variability (natural internal variability in 20-yr means) and $\geq 90\%$ of models agree on sign of change. Colors with white dots indicate areas with strong agreement, where $\geq 66\%$ of models show change greater than the baseline variability and $\geq 66\%$ of models agree on sign of change. Gray indicates areas with divergent changes, where $\geq 66\%$ of models show change greater than the baseline variability, but $< 66\%$ agree on sign of change. Colors with diagonal lines indicate areas with little or no change, where $< 66\%$ of models show change greater than the baseline variability, although there may be significant change at shorter timescales such as seasons, months, or days. Analysis uses model data and methods building from WGI AR5 Figure SPM.8. See also Annex I of WGI AR5. [Boxes 21-2 and CC-RC]

Table 24-1 | Key risks from climate change and the potential for risk reduction through mitigation and adaptation in Asia. Key risks are identified based on assessment of the literature and expert judgments, with supporting evaluation of evidence and agreement in the referenced chapter sections. Each key risk is characterized as very low, low, medium, high, or very high. Risk levels are presented for the near-term era of committed climate change (here, for 2030–2040), in which projected levels of global mean temperature increase do not diverge substantially across emissions scenarios. Risk levels are also presented for the longer term era of climate options (here, for 2080–2100), for global mean temperature increase of 2°C and 4°C above pre-industrial levels. For each time frame, risk levels are estimated for the current state of adaptation and for a hypothetical highly adapted state. As the assessment considers potential impacts on different physical, biological, and human systems, risk levels should not necessarily be used to evaluate relative risk across key risks. Relevant climate variables are indicated by symbols.

Climate-related drivers of impacts							Level of risk & potential for adaptation
Warming trend	Extreme temperature	Extreme precipitation	Drying trend	Damaging cyclone	Sea level	Ocean acidification	Potential for additional adaptation to reduce risk Risk level with high adaptation Risk level with current adaptation
Key risk	Adaptation issues & prospects		Climatic drivers	Timeframe	Risk & potential for adaptation		
Increased risk of crop failure and lower crop production could lead to food insecurity in Asia (<i>medium confidence</i>) [24.4.4]	Autonomous adaptation of farmers on-going in many parts of Asia.			Present Near term (2030–2040) Long term (2080–2100) 2°C 4°C	Very low	Medium	Very high
Water shortage in arid areas of Asia (<i>medium confidence</i>) [24.4.1.3, 24.4.1.4]	Limited capacity for water resource adaptation; options include developing water saving technology, changing drought-resilient crops, building more water reservoirs.			Present Near term (2030–2040) Long term (2080–2100) 2°C 4°C	Very low	Medium	Very high
Increased riverine, coastal, and urban flooding leading to widespread damage to infrastructure, livelihoods, and settlements in Asia (<i>medium confidence</i>) [24.4]	<ul style="list-style-type: none"> Exposure reduction via structural and non-structural measures, effective land-use planning, and selective relocation Reduction in the vulnerability of lifeline infrastructure and services (e.g., water, energy, waste management, food, biomass, mobility, local ecosystems, telecommunications) Construction of monitoring and early warning systems; Measures to identify exposed areas, assist vulnerable areas and households, and diversify livelihoods Economic diversification 			Present Near term (2030–2040) Long-term (2080–2100) 2°C 4°C	Very low	Medium	Very high
Increased risk of flood-related deaths, injuries, infectious diseases and mental disorders (<i>medium confidence</i>) [24.4.6.2, 24.4.6.3, 24.4.6.5]	Disaster preparedness including early-warning systems and local coping strategies.			Present Near term (2030–2040) Long term (2080–2100) 2°C 4°C	Very low	Medium	Very high
Increased risk of heat-related mortality (<i>high confidence</i>) [24.4]	<ul style="list-style-type: none"> Heat health warning systems Urban planning to reduce heat islands; Improvement of the built environment; Development of sustainable cities New work practices to avoid heat stress among outdoor workers 			Present Near term (2030–2040) Long term (2080–2100) 2°C 4°C	Very low	Medium	Very high
Increased risk of drought-related water and food shortage causing malnutrition (<i>high confidence</i>) [24.4]	<ul style="list-style-type: none"> Disaster preparedness including early-warning systems and local coping strategies Adaptive/integrated water resource management Water infrastructure and reservoir development Diversification of water sources including water re-use More efficient use of water (e.g., improved agricultural practices, irrigation management, and resilient agriculture) 			Present Near term (2030–2040) Long term (2080–2100) 2°C 4°C	Very low	Medium	Very high
Increased risk of water and vector-borne diseases (<i>medium confidence</i>) [24.4.6.2, 24.4.6.3, 24.4.6.5]	Early-warning systems, vector control programs, water management and sanitation programs.			Present Near term (2030–2040) Long term (2080–2100) 2°C 4°C	Very low	Medium	Very high

Continued next page →

Table 24-1 (continued)

Key risk	Adaptation issues & prospects	Climatic drivers	Timeframe	Risk & potential for adaptation		
				Very low	Medium	Very high
Exacerbated poverty, inequalities and new vulnerabilities (<i>high confidence</i>) [24.4.5, 24.4.6]	Insufficient emphasis and limited understanding on urban poverty, interaction between livelihoods, poverty and climate change.		Present Near term (2030–2040) Long term (2080–2100) 2°C 4°C	Very low	Medium	Very high
				Very low	Medium	Very high
				Very low	Medium	Very high
				Very low	Medium	Very high
Coral reef decline in Asia (<i>high confidence</i>) [24.4.3.3, 24.4.3.5, CC-CR, CC-OA]	The limited adaptation options include minimizing additional stresses in marine protected areas sited where sea surface temperatures are expected to change least and reef resilience is expected to be highest.		Present Near term (2030–2040) Long term (2080–2100) 2°C 4°C	Very low	Medium	Very high
				Very low	Medium	Very high
				Very low	Medium	Very high
				Very low	Medium	Very high
Mountain-top extinctions in Asia (<i>high confidence</i>) [24.4.2.4, 24.4.2.5]	Adaptation options are limited. Reducing non-climate impacts and maximizing habitat connectivity will reduce risks to some extent, while assisted migration may be practical for some species.		Present Near term (2030–2040) Long term (2080–2100) 2°C 4°C	Very low	Medium	Very high
				Very low	Medium	Very high
				Very low	Medium	Very high
				Very low	Medium	Very high

availability is highly uneven and requires assessment on the sub-regional scale because of Asia's huge range of climates (Pfister et al., 2009).

Adequate water supply is one of the major challenges in many regions (Vörösmarty et al., 2010), particularly Central Asia. Growing demand for water is driven by soaring populations, increasing per capita domestic use due to urbanization and thriving economic growth, and increasing use of irrigation.

24.4.1.2. Observed Impacts

The impact of changes in climate, particularly precipitation, on water resources varies cross Asia (Table SM24-4). There is *medium confidence* that water scarcity in northern China has been exacerbated by decreasing precipitation, doubling population, and expanding water withdrawal (Xu et al., 2010). There is no evidence that suggests significant changes of groundwater in the Kherlen River Basin in Mongolia over the past half century (Brutsaert and Sugita, 2008). Apart from water availability, there is *medium confidence* that climate change also leads to degradation of water quality in most regions of Asia (Delpla et al., 2009; Park et al., 2010), although this is also heavily influenced by human activities (Winkel et al., 2011).

Glaciers are important stores of water and any changes have the potential to influence downstream water supply in the long term (see Section 24.9.2). Glacier mass loss shows a heterogeneous pattern across Asia (Gardner et al., 2013).

Glaciers in the polar section of the Ural Mountains; in the Kodar Mountains of Southeast Siberia; in the Suntar Khayata and Chersky Ranges of Northeast Siberia; in Georgia and Azerbaijan on the southern flank of the Greater Caucasus Range; on the Tibetan Plateau (see Box

3-1) and the surrounding areas; and on Puncak Jaya, Papua, Indonesia lost 9 to 80% of their total area in different periods within the 1895–2010 time interval (Ananicheva et al., 2005, 2006; Anisimov et al., 2008; Prentice and Glidden, 2010; Allison, 2011; Shahgedanova et al., 2012; Yao, T. et al., 2012; Stokes et al., 2013) due to increased temperature (Casassa et al., 2009; Shrestha and Aryal, 2011). Changes in the Kamchatka glaciers are driven by both warming and volcanic activity, with the area of some glaciers decreasing, while others increased because they are covered by ash and clinker (Anisimov et al., 2008).

24.4.1.3. Projected Impacts

Projected impacts of climate change on future water availability in Asia differ substantially among river basins and seasons (A1B scenario with five General Circulation Models (GCMs): Immerzeel et al., 2010; A1B with Meteorological Research Institute of Japan Meteorological Agency (MRI)-Atmospheric General Circulation Models (AGCMs): Nakaegawa et al., 2013). There is *high confidence* that water demand in most Asian countries is increasing because of increases in population, irrigated agriculture (Lal, 2011), and industry.

24.4.1.3.1. Tropical Asia

Future projections (A1B with MRI-AGCMs) suggest a decrease in river runoff in January in the Chao Phraya River basin in Thailand (Champathong et al., 2013). In a study of the Mahanadi River Basin in India, a water availability projection (A2, Coupled General Circulation Model 2 (CGCM2)) indicated increasing possibility of floods in September but increasing water scarcity in April (Asokan and Dutta, 2008).

In the Ganges, an increase in river runoff could offset the large increases in water demand due to population growth in a +4°C world (ensemble

Frequently Asked Questions

FAQ 24.1 | What will the projected impact of future climate change be on freshwater resources in Asia?

Asia is a huge and diverse region, so both climate change and the impact on freshwater resources will vary greatly depending on location. But throughout the region, adequate water resources are particularly important because of the massive population and heavy dependence of the agricultural sector on precipitation, river runoff, and groundwater. Overall, there is *low confidence* in the projections of specifically how climate change will impact future precipitation on a sub-regional scale, and thus in projections of how climate change might impact the availability of water resources. However, water scarcity is expected to be a big challenge in many Asian regions because of increasing water demand from population growth and consumption per capita with higher standards of living. Shrinkage of glaciers in central Asia is expected to increase as a result of climate warming, which will influence downstream river runoff in these regions. Better water management strategies could help ease water scarcity. Examples include developing water saving technologies in irrigation, building reservoirs, increasing water productivity, changing cropping systems, and water reuse.

GCMs), due to a projected large increase in average rainfall, although high uncertainties remain at the seasonal scale (Fung et al., 2011).

24.4.1.3.2. Northern and temperate Asia

Projections (A2 and B2 with the Global Assessment of Security (GLASS) model) suggest an increase in average water availability in Russia in the 2070s (Alcamo et al., 2007). In China, a projection (downscaling Hadley Centre Atmospheric Model version 3H (HadAM3H) A2 and B2 scenarios with the Providing Regional Climates for Impacts Studies (PRECIS) regional model) suggests that there will be insufficient water for agriculture in the 2020s and 2040s due to the increases in water demand for non-agricultural uses, although precipitation may increase in some areas (Xiong et al., 2010). In the late-21st century (MRI-AGCMs, A1B), river discharge in northern Japan is projected to increase in February but decrease in May, due to increased winter precipitation and decreased spring snowmelt (Sato et al., 2013).

24.4.1.3.3. Central and West Asia

Given the already very high level of water stress in many parts of Central Asia, projected temperature increases and precipitation decreases (SRES scenarios from IPCC AR4, 23 models) in the western part of Kazakhstan, Uzbekistan, and Turkmenistan could exacerbate the problems of water shortage and distribution (Lioubimtseva and Henebry, 2009). Considering the dependence of Uzbekistan's economy on its irrigated agriculture, which consumes more than 90% of the available water resources of the Amu Darya basin, climate change impacts on river flows would also strongly affect the economy (Schlüter et al., 2010).

24.4.1.4. Vulnerabilities to Key Drivers

It is suggested that freshwater resources will be influenced by changes in rainfall variability, snowmelt, glacier retreat (Im et al., 2010; Li, Z. et

al., 2010; Sato et al., 2012; Yamanaka et al., 2012; Nakaegawa et al., 2013), or evapotranspiration in the river catchment, which are associated with climate change (Jian et al., 2009). Mismanagement of water resources has increased tension because of water scarcity in arid areas (Biswas and Seetharam, 2008; Lioubimtseva and Henebry, 2009; Siegfried et al., 2010; Aarnoudse et al., 2012). Unsustainable consumption of groundwater for irrigation and other uses is considered to be the main cause of groundwater depletion in the Indian states of Rajasthan, Punjab, and Haryana (Rodell et al., 2009).

24.4.1.5. Adaptation Options

Adaptation of freshwater resources to climate change can be identified as developing adaptive/integrated water resource management (Sadoff and Muller, 2009; Schlüter et al., 2010) of the trade-offs balancing water availability against increasing demand, in order to cope with uncertainty and change (Molle and Hoanh, 2009).

Examples of the options include: developing water saving technologies in irrigation (Ngoundo et al., 2007); water infrastructure development in the Ganges river basin (Bharati et al., 2011); increasing water productivity in the Indus and Ganges river basins (Cai et al., 2010), Taiwan, China, and the Philippines (Barker and Levine, 2012), and Uzbekistan (Tischbein et al., 2011); changing cropping systems and patterns in West Asia (Thomas, 2008); and water reuse in China (Yi et al., 2011). During the second half of the 20th century, Asia built many reservoirs and almost tripled its surface water withdrawals for irrigation (Biemans et al., 2011). Reservoirs partly mitigate seasonal differences and increase water availability for irrigation (Biemans et al., 2011). Water management in river basins would benefit from integrated coordination among countries (Kranz et al., 2010). For example, water management in the Syr Darya river basin relates to Kyrgyzstan, Tajikistan, Uzbekistan, Turkmenistan, and Kazakhstan (Siegfried et al., 2010), while the Indus and Ganges-Brahmaputra-Meghna river basins concern Bangladesh, India, Nepal, and Pakistan (Uprety and Salman, 2011).

24.4.2. Terrestrial and Inland Water Systems

24.4.2.1. Sub-regional Diversity

Boreal forests and grasslands dominate in North Asia, deserts and semi-deserts in Central and West Asia, and alpine ecosystems on the Tibetan Plateau. Human-dominated landscapes predominate in the other sub-regions, but the major natural ecosystems are temperate deciduous and subtropical evergreen forests in East Asia, with boreal forest in the northeast and grasslands and deserts in the west, while Southeast Asia was largely covered in tropical forests. South Asia also has tropical forests, with semi-desert in the northwest and alpine ecosystems in the north. Asia includes several of the world's largest river systems, as well as the world's deepest freshwater lake, Lake Baikal, the semi-saline Caspian Sea, and the saline Aral Sea.

24.4.2.2. Observed Impacts

Biological changes consistent with climate trends have been reported in the north and at high altitudes, where rising temperatures have relaxed constraints on plant growth and the distributions of organisms. Few changes have been reported from tropical lowlands and none linked to climate change with *high confidence*, although data are insufficient to distinguish lack of observations from lack of impacts. Impacts on inland water systems have been difficult to disentangle from natural variability and other human impacts (Bates et al., 2008; Vörösmarty et al., 2010; Zheng, 2011; see Section 4.3.3.3). For example, the shrinking of the Aral Sea over the last 50 years has resulted largely from excessive water extraction from rivers, but was probably exacerbated by decreasing precipitation and increasing temperature (Lioubimtseva and Henebry, 2009; Kostianoy and Kosarev, 2010).

24.4.2.2.1. Phenology and growth rates

In humid temperate East Asia, plant observations and satellite measurements of "greenness" (Normalized Difference Vegetation Index (NDVI); see Section 4.3.2.2) show a trend to earlier leafing in spring since the 1980s, averaging 2 days per decade, although details vary between sites, species, and periods (Table SM24-6; detected with *high confidence* and attributed to warming with *medium confidence*). Earlier spring flowering and delayed autumn senescence have also been recorded (Table SM24-6). Trends in semiarid temperate regions were heterogeneous in space and time (Liu et al., 2013a; Yu, Z. et al., 2013a,b). Earlier greening has been reported from boreal forests (Delbart et al., 2008) and from the Hindu-Kush-Himalayan region (Panday and Ghimire, 2012; Shrestha et al., 2012), but with spatial and temporal heterogeneity. Patterns were also heterogeneous in Central Asia (Kariyeva et al., 2012). On the Tibetan Plateau, spring growth advanced until the mid-1990s, but the trend subsequently differs between areas and NDVI data sets (Yu et al., 2010, 2012; Dong et al., 2013; Jin et al., 2013; Shen et al., 2013; Yu, Z. et al., 2013a; Zhang, G. et al., 2013; Zhang, L. et al., 2013).

Satellite NDVI for Asia for 1988–2010 shows a general greening trend (i.e., increasing NDVI, a rough proxy for increasing plant growth), except where water is limiting (Dorigo et al., 2012). Changes at high latitudes

(>60°N) show considerable spatial and temporal variability, despite a consistent warming trend, reflecting water availability and non-climatic factors (Bi et al., 2013; Jeong et al., 2013). Arctic tundra generally showed increased greening since 1982, while boreal forests were variable (Goetz et al., 2011; de Jong et al., 2012; Epstein et al., 2012; Xu et al., 2013). An overall greening trend for 2000–2011 north of the boreal forest correlated with increasing summer warmth and ice retreat (Dutrieux et al., 2012). In China, trends have varied in space and time, reflecting positive impacts of warming and negative impacts of increasing drought stress (Peng et al., 2011; Sun et al., 2012; Xu et al., 2012). The steppe region of northern Kazakhstan showed an overall browning (decreasing NDVI) trend for 1982–2008, linked to declining precipitation (de Jong et al., 2012). In Central Asia, where NDVI is most sensitive to precipitation (Gessner et al., 2013), there was a heterogeneous pattern for 1982–2009, with an initial greening trend stalled or reversed in some areas (Mohammad et al., 2013).

Tree-ring data for 800–1989 for temperate East Asia suggests recent summer temperatures have exceeded those during past warm periods of similar length, although this difference was not statistically significant (Cook et al., 2012). Where temperature limits tree growth, growth rates have increased with warming in recent decades (Duan et al., 2010; Sano et al., 2010; Shishov and Vaganov, 2010; Borgaonkar et al., 2011; Xu et al., 2011; Chen et al., 2012a,b,c,d, 2013; Li et al., 2012), while where drought limits growth, there have been increases (Li et al., 2006; Davi et al., 2009; Shao et al., 2010; Yang et al., 2010) or decreases (Li et al., 2007; Dulamsuren et al., 2010a, 2011; Kang et al., 2012; Wu et al., 2012; Kharuk et al., 2013; Liu et al., 2013b), reflecting decreasing or increasing water stress (*high confidence* in detection, *medium confidence* in attribution to climate change). In boreal forest, trends varied between species and locations, despite consistent warming (Lloyd and Bunn, 2007; Goetz et al., 2011).

24.4.2.2.2. Distributions of species and biomes

Changes in species distributions consistent with a response to warming have been widely reported: upwards in elevation (Soja et al., 2007; Bickford et al., 2010; Kharuk et al., 2010a,b,e; Moiseev et al., 2010; Chen et al., 2011; Jump et al., 2012; Grigor'ev et al., 2013; Telwala et al., 2013) or polewards (Tougou et al., 2009; Ogawa-Onishi and Berry, 2013) (*high confidence* in detection, *medium confidence* in attribution to climate change). Changes in the distributions of major vegetation types (biomes) have been reported from the north and high altitudes, where trees are invading treeless vegetation, and forest understories are being invaded from adjacent biomes (Kharuk et al., 2006; Soja et al., 2007; Bai et al., 2011; Singh et al., 2012; Wang and Liu, 2012). In central Siberia, dark needle conifers (DNCs) and birch have invaded larch-dominated forest over the last 3 decades (Kharuk et al., 2010c,d; Osawa et al., 2010; Lloyd et al., 2011). Meanwhile, warming has driven larch stand crown closure and larch invasion into tundra at a rate of 3 to 10 m yr⁻¹ in the northern forest-tundra ecotone (Kharuk et al., 2006). Shrub expansion in arctic tundra has also been observed (Blok et al., 2011; Myers-Smith et al., 2011; see Section 28.2.3.1). Soil moisture and light are the main factors governing the forest-steppe ecotone (Soja et al., 2007; Zeng et al., 2008; Eichler et al., 2011; Kukavskaya et al., 2013), and Mongolian taiga forests have responded heterogeneously to recent climate changes, but

declines in larch growth and regeneration are more widespread than increases (Dulamsuren et al., 2010a,b).

24.4.2.2.3. Permafrost

Permafrost degradation, including reduced area and increased active layer thickness, has been reported from parts of Siberia, Central Asia, and the Tibetan Plateau (*high confidence*; Romanovsky et al., 2010; Wu and Zhang, 2010; Zhao et al., 2010; Yang et al., 2013). Most permafrost observatories in Asian Russia show substantial warming of permafrost during the last 20 to 30 years (Romanovsky et al., 2008, 2010). Permafrost formed during the Little Ice Age is thawing at many locations and Late Holocene permafrost has begun to thaw at some undisturbed locations in northwest Siberia. Permafrost thawing is most noticeable within the discontinuous permafrost zone, while continuous permafrost is starting to thaw in a few places, so the boundary between continuous and discontinuous permafrost is moving northward (Romanovsky et al., 2008, 2010).

Thawing permafrost may lead to increasing emissions of greenhouse gases from decomposition of accumulated organic matter (see Sections 4.3.3.4, 19.6.3.5). In Mongolia, mean annual permafrost temperature at 10 to 15 m depth increased over the past 10 to 40 years in the Hovsgol, Hangai, and Hentei Mountain regions. Permafrost warming during the past 15 to 20 years was greater than during the previous 15 to 20 years (Sharkhuu et al., 2008; Zhao et al., 2010). In the Kazakh part of the Tien Shan Mountains, permafrost temperature and active layer thickness have increased since the early 1970s. Significant permafrost warming also occurred in the eastern Tien Shan Mountains, in the headwaters of the Urumqi River (Marchenko et al., 2007; Zhao et al., 2010). Monitoring across the Qinghai-Tibet Plateau over recent decades has also revealed permafrost degradation caused by warming and other impacts. Areas of permafrost are shrinking, the active layer depth is increasing, the lower altitudinal limit is rising, and the seasonal frost depth is thinning (Li et al., 2008; Wu and Zhang, 2010; Zhao et al., 2010). In the alpine headwater regions of the Yangtze and Yellow Rivers, rising temperatures and permafrost degradation have resulted in lower lake levels, drying swamps, and shrinking grasslands (Cheng and Wu, 2007; Wang et al., 2011).

24.4.2.3. Projected Impacts

24.4.2.3.1. Phenology and growth rates

Trends toward an earlier spring greening and longer growing season are expected to continue in humid temperate and boreal forest areas, although photoperiod or chilling requirements may reduce responses to warming in some species (Ge et al., 2013; Hadano et al., 2013; Richardson et al., 2013). Changes in precipitation will be important for semiarid and arid ecosystems, as may the direct impacts of atmospheric carbon dioxide (CO₂) concentrations, making responses harder to predict (Liancourt et al., 2012; Poulter et al., 2013). The “general flowering” at multi-year intervals in lowland rainforests in Southeast Asia is triggered by irregular droughts (Sakai et al., 2006), so changes in drought frequency or intensity could have large impacts.

24.4.2.3.2. Distributions of species and biomes

Climate change is expected to modify the vegetation distribution across the region (Tao and Zhang, 2010; Wang, 2013), but responses will be slowed by limitations on seed dispersal, competition from established plants, rates of soil development, and habitat fragmentation (*high confidence*; Corlett and Westcott, 2013). Rising CO₂ concentrations are expected to favor increased woody vegetation in semiarid areas (*medium confidence*; Higgins and Scheiter, 2012; Donohue et al., 2013; Poulter et al., 2013; Wang, 2013). In North Asia, rising temperatures are expected to lead to large changes in the distribution of potential natural ecosystems (*high confidence*; Ni, 2011; Tchebakova et al., 2011; Insarov et al., 2012; Pearson et al., 2013). It is *likely* that the boreal forest will expand northward and eastward, and that tundra will decrease, although differences in models, time periods, and other assumptions have resulted in widely varying projections for the magnitude of this change (Woodward and Lomas, 2004; Kaplan and New, 2006; Lucht et al., 2006; Golubyatnikov and Denisenko, 2007; Sitch et al., 2008; Korzukhin and Tselniker, 2010; Tchebakova et al., 2010, 2011; Pearson et al., 2013). Boreal forest expansion and the continued invasion of the existing larch-dominated forest by DNCs could lead to larch reaching the Arctic shore, while the traditional area of larch dominance turns into mixed forest (Kharuk et al., 2006, 2010c). Both the replacement of summer-green larch with evergreen conifers and expansion of trees and shrubs into tundra decrease albedo, causing regional warming and potentially accelerating vegetation change (Kharuk et al., 2006, 2010d; McGuire et al., 2007; Pearson et al., 2013). The future direction and rate of change of steppe vegetation are unclear because of uncertain precipitation trends (Golubyatnikov and Denisenko, 2007; Tchebakova et al., 2010). The role of CO₂ fertilization is also potentially important here (Poulter et al., 2013; see WGI AR5 Box 6.3).

In East Asia, subtropical evergreen forests are projected to expand north into the deciduous forest and tropical forests to expand along China’s southern coast (Choi et al., 2011; Wang, 2013), but vegetation change may lag climate change by decades or centuries (Corlett and Westcott, 2013). On the Tibetan Plateau, projections suggest that alpine vegetation will be largely replaced by forest and shrubland, with tundra and steppe retreating to the north (Liang et al., 2012; Wang, 2013). Impacts in Central and West Asia will depend on changes in precipitation. In India, a dynamic vegetation model (A2 and B2 scenarios) projected changes in more than a third of the forest area by 2100, mostly from deciduous to evergreen forest in response to increasing rainfall, although fragmentation and other human pressures are expected to slow these changes (Chaturvedi et al., 2011). By 2100, large areas of tropical and subtropical lowland Asia are projected to experience combinations of temperature and rainfall outside the current global range, under a variety of model projections and emission scenarios (Williams et al., 2007; Beaumont et al., 2010; García-López and Allué, 2013), but the potential impacts of these novel conditions on biodiversity are largely unknown (Corlett, 2011).

In Southeast Asia, projected climate (A2 and B1 scenarios) and vegetation changes are expected to produce widespread declines in bat species richness, northward range shifts for many species, and large reductions in the distributions of most species (Hughes et al., 2012). Projections for various bird species in Asia under a range of scenarios also suggest

major impacts on distributions (Menon et al., 2009; Li, R. et al., 2010; Ko et al., 2012). Projections for butterflies in Thailand (A2 and B2 scenarios) suggest that species richness within protected areas will decline approximately 30% by 2070–2099 (Klorvuttimontara et al., 2011). Projections for dominant bamboos in the Qinling Mountains (A2 and B2 scenarios) suggest substantial range reductions by 2100, with potentially adverse consequences for the giant pandas that eat them (Tuanmu et al., 2012). Projections for snow leopard habitat in the Himalayas (B1, A1B, and A2 scenarios) suggest contraction by up to 30% as forests replace open habitats (Forrest et al., 2012).

24.4.2.3.3. Permafrost

In the Northern Hemisphere, a 20 to 90% decrease in permafrost area and a 50 to 300 cm increase in active layer thickness driven by surface warming is projected for 2100 by different models and scenarios (Schaefer et al., 2011). It is *likely* that permafrost degradation in North Asia will spread from the southern and low-altitude margins, advancing northward and upward, but rates of change vary greatly between model projections (Cheng and Wu, 2007; Riseborough et al., 2008; Romanovsky et al., 2008; Anisimov, 2009; Eliseev et al., 2009; Nadyozhina et al., 2010; Schaefer et al., 2011; Wei et al., 2011). Substantial retreat is also expected on the Qinghai-Tibet Plateau (Cheng and Wu, 2007). Near-surface permafrost is expected to remain only in Central and Eastern Siberia and parts of the Qinghai-Tibet Plateau in the late-21st century.

24.4.2.3.4. Inland waters

Climate change impacts on inland waters will interact with dam construction, pollution, and land use changes (Vörösmarty et al., 2010; see also Sections 3.3.2, 24.9.1). Increases in water temperature will impact species- and temperature-dependent processes (Hamilton, 2010; Dudgeon, 2011, 2012). Coldwater fish will be threatened as rising water temperatures make much of their current habitat unsuitable (Yu, D. et al., 2013). Climate change is also expected to change flow regimes in running waters and consequently impact habitats and species that are sensitive to droughts and floods (see Box CC-RF). Habitats that depend on seasonal inundation, including floodplain grasslands and freshwater swamp forests, will be particularly vulnerable (Maxwell, 2009; Bezuijen, 2011; Arias et al., 2012). Reduced dry season flows are expected to combine with sea level rise to increase saltwater intrusion in deltas (Hamilton, 2010; Dudgeon, 2012), although non-climatic impacts will continue to dominate in most estuaries (Syvitski et al., 2009). For most Asian lakes, it is difficult to disentangle the impacts of water pollution, hydro-engineering, and climate change (Battarbee et al., 2012).

24.4.2.4. Vulnerabilities to Key Drivers

Permafrost melting in response to warming is expected to impact ecosystems across large areas (*high confidence*; Cheng and Wu, 2007; Tchebakova et al., 2011). The biodiversity of isolated mountains may also be particularly vulnerable to warming, because many species already have small geographical ranges that will shrink further (La Sorte and Jetz, 2010; Liu et al., 2010; Chou et al., 2011; Noroozi et al., 2011; Peh

et al., 2011; Jump et al., 2012; Tanaka, N. et al., 2012; Davydov et al., 2013). Many freshwater habitats are similarly isolated and their restricted-range species may be equally vulnerable (Dudgeon, 2012). In flatter topography, higher velocities of climate change (the speeds that species need to move to maintain constant climate conditions) increase the vulnerabilities of species that are unable to keep pace, as a result of limited dispersal ability, habitat fragmentation, or other non-climatic constraints (Corlett and Westcott, 2013). In the tropics, temperature extremes above the present range are a potential threat to organisms and ecosystems (Corlett, 2011; Jevanandam et al., 2013; Mumby et al., 2013). For much of interior Asia, increases in drought stress, as a result of declining rainfall and/or rising temperatures, are the key concern. Because aridity is projected to increase in the northern Mongolian forest belt during the 21st century (Sato et al., 2007), larch cover will likely be reduced (Dulamsuren et al., 2010a). In the boreal forest region, a longer, warmer growing season will increase vulnerability to fires, although other human influences may overshadow climate impacts in accessible areas (Flannigan et al., 2009; Liu et al., 2012; Li et al., 2013; see Section 4.3.3.1.1). If droughts intensify in lowland Southeast Asia, the synergies between warmth, drought, logging, fragmentation, and fire (Daniau et al., 2012) and tree mortality (Kumagai and Porporato, 2012; Tan et al., 2013), possibly exacerbated by feedbacks between deforestation, smoke aerosols, and reduced rainfall (Aragão, 2012; Tosca et al., 2012), could greatly increase the vulnerability of fragmented forest landscapes (*high confidence*).

24.4.2.5. Adaptation Options

Suggested strategies for maximizing the adaptive capacity of ecosystems include reducing non-climate impacts, maximizing landscape connectivity, and protecting “refugia” where climate change is expected to be less than the regional mean (Hannah, 2010; Game et al., 2011; Klorvuttimontara et al., 2011; Murthy et al., 2011; Ren et al., 2011; Shoo et al., 2011; Mandych et al., 2012). Additional options for inland waters include operating dams to maintain environmental flows for biodiversity, protecting catchments, and preserving river floodplains (Vörösmarty et al., 2010). Habitat restoration may facilitate species movements across climatic gradients (Klorvuttimontara et al., 2011; Hughes et al., 2012) and long-distance seed dispersal agents may need protection (McConkey et al., 2012). Assisted migration of genotypes and species is possible where movements are constrained by poor dispersal, but risks and benefits need to be considered carefully (Liu et al., 2010; Olden et al., 2010; Tchebakova et al., 2011; Dudgeon, 2012; Ishizuka and Goto, 2012; Corlett and Westcott, 2013). *Ex situ* conservation can provide backup for populations and species most at risk from climate change (Chen et al., 2009).

24.4.3. Coastal Systems and Low-Lying Areas

24.4.3.1. Sub-regional Diversity

Asia’s coastline includes the global range of shore types. Tropical and subtropical coasts support approximately 45% of the world’s mangrove forest (Giri et al., 2011) and low-lying areas in equatorial Southeast Asia support most of the world’s peat swamp forests, as well as other

forested swamp types. Intertidal salt marshes are widespread along temperate and arctic coasts, while a variety of non-forested wetlands occur inland. Asia supports approximately 40% of the world's coral reef area, mostly in Southeast Asia, with the world's most diverse reef communities in the "coral triangle" (Spalding et al., 2001; Burke et al., 2011). Seagrass beds are widespread and support most of the world's seagrass species (Green and Short, 2003). Six of the seven species of sea turtle are found in the region and five nest on Asian beaches (Spotila, 2004). Kelp forests and other seaweed beds are important on temperate coasts (Bolton, 2010; Nagai et al., 2011). Arctic sea ice supports a specialized community of mammals and other organisms (see Sections 28.2.3.3-4.).

24.4.3.2. Observed Impacts

Most of Asia's non-Arctic coastal ecosystems are under such severe pressure from non-climate impacts that climate impacts are hard to detect (see Section 5.4.2). Most large deltas in Asia are sinking (as a result of groundwater withdrawal, floodplain engineering, and trapping of sediments by dams) much faster than global sea level is rising (Syvitski et al., 2009). Widespread impacts can be attributed to climate change only for coral reefs, where the temporal and spatial patterns of bleaching correlate with higher than normal sea surface temperatures (*very high confidence*; Section 5.4.2.4; Box CC-CR). Increased water temperatures may also explain declines in large seaweed beds in temperate Japan (Nagai et al., 2011; Section 5.4.2.3). Warming coastal waters have also been implicated in the northward expansion of tropical and subtropical macroalgae and toxic phytoplankton (Nagai et al., 2011), fish (Tian et al., 2012), and tropical corals, including key reef-forming species (Yamano et al., 2011), over recent decades. The decline of large temperate seaweeds and expansion of tropical species in southwest Japan has been linked to rising sea surface temperatures (Tanaka, K. et al., 2012), and these changes have impacted fish communities (Terazono et al., 2012).

In Arctic Asia, changes in permafrost and the effects of sea level rise and sea ice retreat on storm-wave energy have increased erosion (Are et al., 2008; Razumov, 2010; Handmer et al., 2012). Average erosion rates range from 0.27 m yr⁻¹ (Chukchi Sea) to 0.87 m yr⁻¹ (East Siberian Sea), with a number of segments in the Laptev and East Siberian Sea experiencing rates greater than 3 m yr⁻¹ (Lantuit et al., 2012).

24.4.3.3. Projected Impacts

Marine biodiversity at temperate latitudes is expected to increase as temperature constraints on warmwater taxa are relaxed (*high confidence*; see Section 6.4.1.1), but biodiversity in tropical regions may fall if, as evidence suggests, tropical species are already near their thermal maxima (*medium confidence*; Cheung et al., 2009, 2010; Nguyen et al., 2011). Individual fish species are projected to shift their ranges northward in response to rising sea surface temperatures (Tseng et al., 2011; Okunishi et al., 2012; Tian et al., 2012). The combined effects of changes in distribution, abundance, and physiology may reduce the body size of marine fishes, particularly in the tropics and intermediate latitudes (Cheung et al., 2013).

Continuation of current trends in sea surface temperatures and ocean acidification would result in large declines in coral-dominated reefs by mid-century (*high confidence*; Burke et al., 2011; Hoegh-Guldberg, 2011; see Section 5.4.2.4; Box CC-CR). Warming would permit the expansion of coral habitats to the north but acidification is expected to limit this (Yara et al., 2012). Acidification is also expected to have negative impacts on other calcified marine organisms (algae, molluscs, larval echinoderms), while impacts on non-calcified species are unclear (Branch et al., 2013; Kroeker et al., 2013; see Box CC-OA). On rocky shores, warming and acidification are expected to lead to range shifts and changes in biodiversity (see Section 5.4.2.2).

Future rates of sea level rise are expected to exceed those of recent decades (see WGI AR5 Section 13.5.1), increasing coastal flooding, erosion, and saltwater intrusion into surface and groundwaters. In the absence of other impacts, coral reefs may grow fast enough to keep up with rising sea levels (Brown et al., 2011; Villanoy et al., 2012; see Section 5.4.2.4), but beaches may erode and mangroves, salt marshes, and seagrass beds will decline, unless they receive sufficient fresh sediment to keep pace or they can move inland (Gilman et al., 2008; Bezuijen, 2011; Kintisch, 2013; see Section 5.3.2.3). Loucks et al. (2010) predict a 96% decline in tiger habitat in Bangladesh's Sunderbans mangroves with a 28 cm sea level rise if sedimentation does not increase surface elevations. Rising winter temperatures are expected to result in poleward expansion of mangrove ecosystems (see Section 5.4.2.3). Coastal freshwater wetlands may be vulnerable to saltwater intrusion with rising sea levels, but in most river deltas local subsidence for non-climatic reasons will be more important (Syvitski et al., 2009). Current trends in cyclone frequency and intensity are unclear (Section 24.3.2; Box CC-TC), but a combination of cyclone intensification and sea level rise could increase coastal flooding (Knutson et al., 2010) and losses of coral reefs and mangrove forests would exacerbate wave damage (Gedan et al., 2011; Villanoy et al., 2012).

In the Asian Arctic, rates of coastal erosion are expected to increase as a result of interactions between rising sea levels and changes in permafrost and the length of the ice-free season (*medium evidence*; *high agreement*; Pavlidis et al., 2007; Lantuit et al., 2012). The largest changes are expected for coasts composed of loose permafrost rocks and therefore subject to intensive thermal abrasion. If sea level rises by 0.5 m over this century, modeling studies predict that the rate of recession will increase 1.5- to 2.6-fold for the coasts of the Laptev Sea, East Siberian Sea, and West Yamal in the Kara Sea, compared to the rate observed in the first years of the 21st century.

24.4.3.4. Vulnerabilities to Key Drivers

Offshore marine systems are most vulnerable to rising water temperatures and ocean acidification, particularly for calcifying organisms such as corals. Sea level rise will be the key issue for many coastal areas, particularly if combined with changes in cyclone frequency or intensity, or, in Arctic Asia, with a lengthening open-water season. The expected continuing decline in the extent of sea ice in the Arctic may threaten the survival of some ice-associated organisms (see Section 28.2.2.1), with expanded human activities in previously inaccessible areas an additional concern (Post et al., 2013).

24.4.3.5. Adaptation Options

The connectivity of marine habitats and dispersal abilities of marine organisms increase the capacity for autonomous (spontaneous) adaptation in coastal systems (Cheung et al., 2009). Creating marine protected areas where sea surface temperatures are projected to change least may increase their future resilience (Levy and Ban, 2013). For coral reefs, potential indicators of future resilience include later projected onset of annual bleaching conditions (van Hooidonk et al., 2013), past temperature variability, the abundance of heat-tolerant coral species, coral recruitment rates, connectivity, and macroalgae abundance (McClanahan et al., 2012). Similar strategies may help identify reefs that are more resilient to acidification (McLeod et al., 2013). Hard coastal defenses, such as sea walls, protect settlements at the cost of preventing adjustments by mangroves, salt marshes, and seagrass beds to rising sea levels. Landward buffer zones that provide an opportunity for future inland migration could mitigate this problem (Tobey et al., 2010). More generally, maintaining or restoring natural shorelines where possible is expected to provide coastal protection and other benefits (Tobey et al., 2010; Crooks et al., 2011). Projected increases in the navigability of the Arctic Ocean because of declining sea ice suggest the need for a revision of environmental regulations to minimize the risk of marine pollution (Smith and Stephenson, 2013).

24.4.4. Food Production Systems and Food Security

It is projected that climate change will affect food security by the middle of the 21st century, with the largest numbers of food-insecure people located in South Asia (see Chapter 7).

24.4.4.1. Sub-regional Diversity

WGII AR4 Section 10.4.1.1 pointed out that there will be regional differences within Asia in the impacts of climate change on food production. Research since then has validated this divergence and new data are available especially for West and Central Asia (see Tables SM24-4, SM24-5). In WGII AR4 Section 10.4.1, climate change was projected to lead mainly to reductions in crop yield. New research shows there will also be gains for specific regions and crops in given areas. Thus, the current assessment encompasses an enormous variability, depending on the regions and the crops grown.

24.4.4.2. Observed Impacts

There are very limited data globally for observed impacts of climate change on food production systems (see Chapter 7) and this is true also for Asia. In Jordan, it was reported that the total production and average yield for wheat and barley were lowest in 1999 for the period 1996–2006 (Al-Bakri et al., 2010), which could be explained by the low rainfall during that year, which was 30% of the average (*high confidence* in detection, *low confidence* in attribution). In China, rice yield responses to recent climate change at experimental stations were assessed for the period 1981–2005 (Zhang et al., 2010). In some places, yields were positively correlated with temperature when they were also positively

related with solar radiation. However, in other places, lower yield with higher temperature was accompanied by a positive correlation between yield and rainfall (*high confidence* in detection, *high confidence* in attribution). In Japan, where mean air temperature rose by about 1°C over the 20th century, effects of recent warming include phenological changes in many crops, increases in fruit coloring disorders and incidences of chalky rice kernels, reductions in yields of wheat, barley, vegetables, flowers, milk, and eggs, and alterations in the type of disease and pest (*high confidence* in detection, *high confidence* in attribution; Sugiura et al., 2012).

24.4.4.3. Projected Impacts

24.4.4.3.1. Production

WGII AR4 Section 10.4.1.1 mainly dealt with cereal crops (rice, wheat, corn). Since then, impacts of climate change have been modeled for additional cereal crops and sub-regions. It is *very likely* that climate change effects on crop production in Asia will be variable, negative for specific regions and crops in given areas and positive for other regions and crops (*medium evidence, high agreement*). It is also *likely* that an elevated CO₂ concentration in the atmosphere will be beneficial to most crops (*medium evidence, high agreement*).

In semiarid areas, rainfed agriculture is sensitive to climate change both positively and negatively (Ratnakumar et al., 2011). In the mountainous Swat and Chitral districts of Pakistan (average altitudes 960 and 1500 m above sea level, respectively), there were mixed results as well (Hussain and Mudasser, 2007). Projected temperature increases of 1.5°C and 3°C would lead to wheat yield declines (by 7% and 24%, respectively) in Swat district but to increases (by 14% and 23%) in Chitral district. In India, climate change impacts on sorghum were analyzed using the InfoCrop-SORGHUM simulation model (Srivastava et al., 2010). A changing climate was projected to reduce monsoon sorghum grain yield by 2 to 14% by 2020, with worsening yields by 2050 and 2080. In the Indo-Gangetic Plains, a large reduction in wheat yields is projected (see Section 24.4.4.3.2), unless appropriate cultivars and crop management practices are adopted (Ortiz et al., 2008). A systematic review and meta-analysis of data in 52 original publications projected mean changes in yield by the 2050s across South Asia of 16% for maize and 11% for sorghum (Knox et al., 2012). No mean change in yield was projected for rice.

In China, modeling studies of the impacts of climate change on crop productivity have had mixed results. Rice is the most important staple food in Asia. Studies show that climate change will alter productivity in China but not always negatively. For example, an ensemble-based probabilistic projection shows rice yield in eastern China would change on average by 7.5 to 17.5% (–10.4 to 3.0%), 0.0 to 25.0% (–26.7 to 2.1%), and –10.0 to 25.0% (–39.2 to –6.4%) during the 2020s, 2050s, and 2080s, respectively, in response to climate change, with (without) consideration of CO₂ fertilization effects, using all 10 combinations of two emission scenarios (A1FI and B1) and five GCMs (Hadley Centre climate prediction model 3 (HadCM3), Parallel Climate Model (PCM), CGCM2, Commonwealth Scientific and Industrial Research Organisation 2 (CSIRO2), and European Centre for Medium Range Weather Forecasts

Frequently Asked Questions

FAQ 24.2 | How will climate change affect food production and food security in Asia?

Climate change impacts on temperature and precipitation will affect food production and food security in various ways in specific areas throughout this diverse region. Climate change will have a generally negative impact on crop production Asia, but with diverse possible outcomes (*medium confidence*). For example most simulation models show that higher temperatures will lead to lower rice yields as a result of a shorter growing period. But some studies indicate that increased atmospheric CO₂ that leads to those higher temperatures could enhance photosynthesis and increase rice yields. This uncertainty on the overall effects of climate change and CO₂ fertilization is generally true for other important food crops such as wheat, sorghum, barley, and maize, among others.

Yields of some crops will increase in some areas (e.g., cereal production in north and east Kazakhstan) and decrease in others (e.g., wheat in the Indo-Gangetic Plain of South Asia). In Russia, climate change may lead to a food production shortfall, defined as an event in which the annual potential production of the most important crops falls 50% or more below its normal average. Sea level rise is projected to decrease total arable areas and thus food supply in many parts of Asia. A diverse mix of potential adaptation strategies, such as crop breeding, changing crop varieties, adjusting planting time, water management, diversification of crops, and a host of indigenous practices will all be applicable within local contexts.

and Hamburg 4 (ECHAM4)) relative to 1961–1990 levels (Tao and Zhang, 2013a). With rising temperatures, the process of rice development accelerates and reduces the duration for growth. Wassmann et al. (2009a,b) concluded that, in terms of risks of increasing heat stress, there are parts of Asia where current temperatures are already approaching critical levels during the susceptible stages of the rice plant. These include Pakistan/North India (October), South India (April/August), East India/Bangladesh (March–June), Myanmar/Thailand/Laos/Cambodia (March–June), Vietnam (April/August), Philippines (April/June), Indonesia (August), and China (July/August).

There have also been simulation studies for other crops in China. In the Huang-Hai Plain, China's most productive wheat growing region, modeling indicated that winter wheat yields would increase on average by 0.2 Mg ha⁻¹ in 2015–2045 and by 0.8 Mg ha⁻¹ in 2070–2099, due to warmer nighttime temperatures and higher precipitation, under A2 and B2 scenarios using the HadCM3 model (Thomson et al., 2006). In the North China Plain, an ensemble-based probabilistic projection projected that maize yield will change by –9.7 to –9.1%, –19.0 to –15.7%, and –25.5 to –24.7%, during 2020s, 2050s, and 2080s as a percentage of 1961–1990 yields (Tao et al., 2009). In contrast, winter wheat yields could increase with high probability in future due to climate change (Tao and Zhang, 2013b).

It should be noted that crop physiology simulation models may overstate the impact of CO₂ fertilization. Free Atmosphere Carbon Exchange (FACE) experiments show that measurable CO₂ fertilization effects are typically less than modeled results (see Section 7.3).

Extreme weather events are also expected to negatively affect agricultural crop production (IPCC, 2012). For example, extreme temperatures could lower yields of rice (Mohammed and Tarpley, 2009; Tian et al., 2010). With higher precipitation, flooding could also lead to lower crop production (see SREX Chapter 4).

24.4.4.3.2. Farming systems and crop areas

Since the release of the AR4 (see WGII AR4 Section 10.4.1.2), more information is available on the impacts of climate change on farming systems and cropping areas in more countries in Asia and especially in Central Asia. Recent studies validate the likely northward shifts of crop production with current croplands under threat from the impacts of climate change (*medium evidence, medium agreement*). Cooler regions are likely to benefit as warmer temperatures increase arable areas (*medium evidence, high agreement*).

Central Asia is expected to become warmer in the coming decades and increasingly arid, especially in the western parts of Turkmenistan, Uzbekistan, and Kazakhstan (Lioubimtseva and Henebry, 2009). Some parts of the region could be winners (cereal production in northern and eastern Kazakhstan could benefit from the longer growing season, warmer winters, and a slight increase in winter precipitation), while others could be losers (particularly western Turkmenistan and Uzbekistan, where frequent droughts could negatively affect cotton production, increase already extremely high water demands for irrigation, and exacerbate the already existing water crisis and human-induced desertification). In India, the Indo-Gangetic Plains are under threat of a significant reduction in wheat yields (Ortiz et al., 2008). This area produces 90 million tons of wheat grain annually (about 14 to 15% of global wheat production). Climate projections based on a doubling of CO₂ using a CCM3 model downscaled to a 30 arc-second resolution as part of the WorldClim data set showed that there will be a 51% decrease in the most favorable and high yielding area due to heat stress. About 200 million people (using the current population) in this area whose food intake relies on crop harvests would experience adverse impacts.

Rice growing areas are also expected to shift with climate change throughout Asia. In Japan, increasing irrigation water temperature (1.6°C to 2.0°C) could lead to a northward shift of the isochrones of

safe transplanting dates for rice seedlings (Ohta and Kimura, 2007). As a result, rice cultivation period will be prolonged by approximately 25 to 30 days. This will allow greater flexibility in the cropping season than at present, resulting in a reduction in the frequency of cool-summer damage in the northern districts. Sea level rise threatens coastal and deltaic rice production areas in Asia, such as those in Bangladesh and the Mekong River Delta (Wassmann et al., 2009b). For example, about 7% of Vietnam's agriculture land may be submerged due to 1-m sea level rise (Dasgupta et al., 2009). In Myanmar, saltwater intrusion due to sea level rise could also decrease rice yield (Wassmann et al., 2009b).

24.4.4.3.3. Fisheries and aquaculture

Asia dominates both capture fisheries and aquaculture (FAO, 2010). More than half of the global marine fish catch in 2008 was in the West Pacific and Indian Ocean, and the lower Mekong River basin supports the largest freshwater capture fishery in the world (Dudgeon, 2011). Fish production is also a vital component of regional livelihoods, with 85.5% of the world's fishers (28 m) and fish farmers (10 m) in Asia in 2008. Many more people fish part time. Fish catches in the Asian Arctic are relatively small, but important for local cultures and regional food security (Zeller et al., 2011).

Inland fisheries will continue to be vulnerable to a wide range of ongoing threats, including overfishing, habitat loss, water abstraction, drainage of wetlands, pollution, and dam construction, making the impacts of climate change hard to detect (see also Section 24.9.1). Most concerns have centered on rising water temperatures and the potential impacts of climate change on flow regimes, which in turn are expected to affect the reproduction of many fish species (Allison et al., 2009; Barange and Perry, 2009; Bezuijen, 2011; Dudgeon, 2011; see also Section 24.4.2.3). Sea level rise is expected to impact both capture fisheries and aquaculture production in river deltas (De Silva and Soto, 2009). For marine capture fisheries, Cheung et al. (2009, 2010) used a dynamic bioclimate envelope model to project the distributions of 1066 species of exploited marine fish and invertebrates for 2005–2055, based on the SRES A1B scenario and a stable-2000 CO₂ scenario. This analysis suggests that climate change may lead to a massive redistribution of fisheries catch potential, with large increases in high-latitude regions, including Asian Russia, and large declines in the tropics, particularly Indonesia. Other studies have made generally similar predictions, with climate change impacts on marine productivity expected to be large and negative in the tropics, in part because of the vulnerability of coral reefs to both warming and ocean acidification (see also Section 24.4.3.3), and large and positive in Arctic and sub-Arctic regions, because of sea ice retreat and poleward species shifts (*high confidence*; Sumaila et al., 2011; Blanchard et al., 2012; Doney et al., 2012). Predictions of a reduction in the average maximum body weight of marine fishes by 14 to 24% by 2050 under a high-emission scenario are an additional threat to fisheries (Cheung et al., 2013).

24.4.4.3.4. Future food supply and demand

WGII AR4 Section 10.4.1.4 was largely based on global models that included Asia. There are now a few quantitative studies in Asia and its individual countries. In general, these show that the risk of hunger, food

insecurity, and loss of livelihood due to climate change will *likely* increase in some regions (*low evidence, medium agreement*).

Rice is a key staple crop in Asia and 90% or more of the world's rice production is from Asia. An Asia-wide study revealed that climate change scenarios (using 18 GCMs for A1B, 14 GCMs for A2, and 17 GCMs for B1) would reduce rice yield over a large portion of the continent (Masutomi et al., 2009). The most vulnerable regions were western Japan, eastern China, the southern part of the Indochina peninsula, and the northern part of South Asia. In Russia, climate change may also lead to "food production shortfall," which was defined as an event in which the annual potential (i.e., climate-related) production of the most important crops in an administrative region in a specific year falls below 50% of its climate-normal (1961–1990) average (Alcamo et al., 2007). The study shows that the frequency of shortfalls in five or more of the main crop growing regions in the same year is around 2 years per decade under normal climate but could climb to 5 to 6 years per decade in the 2070s, depending on the scenario and climate model (using the GLASS, Global Agro-Ecological Zones (GAEZ), and Water-Global Assessment and Prognosis (WaterGAP-2) models and ECHAM and HadCM3 under the A2 and B2 scenarios). The increasing shortfalls were attributed to severe droughts. The study estimated that the number of people living in regions that may experience one or more shortfalls each decade may grow to 82 to 139 million in the 2070s. Increasing frequency of extreme climate events will pose an increasing threat to the security of Russia's food system.

In contrast, climate change may provide a windfall for wheat farmers in parts of Pakistan. Warming temperatures would make it possible to grow at least two crops (wheat and maize) a year in mountainous areas (Hussain and Mudasser, 2007). In the northern mountainous areas, wheat yield was projected to increase by 50% under SRES A2 and by 40% under the B2 scenario, whereas in the sub-mountainous, semiarid, and arid areas, it is *likely* to decrease by the 2080s (Iqbal et al., 2009).

24.4.4.4. Vulnerabilities to Key Drivers

Food production and food security are most vulnerable to rising air temperatures (Wassmann et al., 2009a,b). Warmer temperatures could depress yields of major crops such as rice. However, warmer temperatures could also make some areas more favorable for food production (Lioubimtseva and Henebry, 2009). Increasing CO₂ concentration in the atmosphere could lead to higher crop yields (Tao and Zhang, 2013a). Sea level rise will be a key issue for many coastal areas as rich agricultural lands may be submerged and taken out of production (Wassmann et al., 2009b).

24.4.4.5. Adaptation Options

Since AR4, there have been additional studies of recommended and potential adaptation strategies and practices in Asia (Table SM24-7) and there is new information for West and Central Asia. There are also many more crop-specific and country-specific adaptation options available. Farmers have been adapting to climate risks for generations. Indigenous and local adaptation strategies have been documented for

Southeast Asia (Peras et al., 2008; Lasco et al., 2010, 2011) and could be used as a basis for future climate change adaptation. Crop breeding for high temperature conditions is a promising option for climate change adaptation in Asia. For example, in the North China Plain, simulation studies show that using high-temperature sensitive varieties, maize yield in the 2050s could increase on average by 1.0 to 6.0%, 9.9 to 15.2%, and 4.1 to 5.6%, by adopting adaptation options of early planting, fixing variety growing duration, and late planting, respectively (Tao and Zhang, 2010). In contrast, no adaptation will result in yield declines of 13.2 to 19.1%.

24.4.5. Human Settlements, Industry, and Infrastructure

24.4.5.1. Sub-regional Diversity

Around one in every five urban dwellers in Asia lives in large urban agglomerations and almost 50% of these live in small cities (UN DESA Population Division, 2012). North and Central Asia are the most urbanized areas, with more than 63% of the population living in urban areas, with the exception of Kyrgyzstan and Tajikistan (UN-HABITAT, 2010; UN ESCAP, 2011). South and Southwest Asia are the least urbanized sub-regions, with only a third of their populations living in urban areas. However, these regions have the highest urban population growth rates within Asia, at an average of 2.4% per year during 2005–2010 (UN ESCAP, 2011). By the middle of this century, Asia's urban population will increase by 1.4 billion and will account for more than 50% of the global population (UN DESA Population Division, 2012).

24.4.5.2. Observed Impacts

Asia experienced the highest number of weather- and climate-related disasters in the world during the period 2000–2008 and suffered huge economic losses, accounting for the second highest proportion (27.5%) of the total global economic loss (IPCC, 2012). Flood mortality risk is heavily concentrated in Asia. Severe floods in Mumbai in 2005 have been attributed to both climatic factors and non-climatic factors. Strengthened capacities to address the mortality risk associated with major weather-related hazards, such as floods, have resulted in a downward trend in mortality risk relative to population size, as in East Asia, where it is now a third of its 1980 level (UNISDR, 2011).

24.4.5.3. Projected Impacts

A large proportion of Asia's population lives in low elevation coastal zones that are particularly at risk from climate change hazards, including sea level rise, storm surges, and typhoons (see Sections 5.3.2.1, 8.2.2.5; Box CC-TC). Depending on region, half to two-thirds of Asia's cities with 1 million or more inhabitants are exposed to one or multiple hazards, with floods and cyclones most important (UN DESA Population Division, 2012).

24.4.5.3.1. Floodplains and coastal areas

Three of the world's five most populated cities (Tokyo, Delhi, and Shanghai) are located in areas with high risk of floods (UN DESA Population Division,

2012). Flood risk and associated human and material losses are heavily concentrated in India, Bangladesh, and China. At the same time, the East Asia region in particular is experiencing increasing water shortages, negatively affecting its socioeconomic, agricultural, and environmental conditions, which is attributed to lack of rains and high evapotranspiration, as well as over-exploitation of water resources (IPCC, 2012). Large parts of South, East, and Southeast Asia are exposed to a high degree of cumulative climate-related risk (UN-HABITAT, 2011). Asia has more than 90% of the global population exposed to tropical cyclones (IPCC, 2012; see Box CC-TC). Damage due to storm surge is sensitive to change in the magnitude of tropical cyclones. By the 2070s, the top Asian cities in terms of population exposure (including all environmental and socioeconomic factors) to coastal flooding are expected to be Kolkata, Mumbai, Dhaka, Guangzhou, Ho Chi Minh City, Shanghai, Bangkok, Rangoon, and Hai Phòng (Hanson et al., 2011). The top Asian cities in terms of assets exposed are expected to be Guangzhou, Kolkata, Shanghai, Mumbai, Tianjin, Tokyo, Hong Kong, and Bangkok. Asia includes 15 of the global top 20 cities for projected population exposure and 13 of the top 20 for asset exposure.

24.4.5.3.2. Other issues in human settlements

Asia has a large—and rapidly expanding—proportion of the global urban exposure and vulnerability related to climate change hazards (see SREX Section 4.4.3). In line with the rapid urban growth and sprawl in many parts of Asia, the periurban interface between urban and rural areas deserves particular attention when considering climate change vulnerability (see also Section 18.4.1). Garschagen et al. (2011) find, for example, that periurban agriculturalists in the Vietnamese Mekong Delta are facing a multiple burden because they are often exposed to overlapping risks resulting from (1) socioeconomic transformations, such as land title insecurity and price pressures; (2) local biophysical degradation, as periurban areas serve as sinks for urban wastes; and (3) climate change impacts, as they do not benefit from the inner-urban disaster risk management measures. Nevertheless, the periurban interface is still underemphasized in studies on impacts, vulnerability, and adaptation in Asia.

Groundwater sources, which are affordable means of high-quality water supply in cities of developing countries, are threatened due to over-withdrawals. Aquifer levels have fallen by 20 to 50 m in cities such as Bangkok, Manila, and Tianjin and between 10 and 20 m in many other cities (UNESCO, 2012). The drop in groundwater levels often results in land subsidence, which can enhance hazard exposure due to coastal inundation and sea level rise, especially in settlements near the coast, and deterioration of groundwater quality. Cities susceptible to human-induced subsidence (developing country cities in deltaic regions with rapidly growing populations) could see significant increases in exposure (Nicholls et al., 2008). Settlements on unstable slopes or landslide-prone areas face increased prospects of rainfall-induced landslides (IPCC, 2012).

24.4.5.3.3. Industry and infrastructure

The impacts of climate change on industry include both direct impacts on industrial production and indirect impacts on industrial enterprises

due to the implementation of mitigation activities (Li, 2008). The impact of climate change on infrastructure deterioration cannot be ignored, but can be addressed by changes to design procedures, including increases in cover thickness, improved quality of concrete, and coatings and barriers (Stewart et al., 2012). Climate change and extreme events may have a greater impact on large and medium-sized construction projects (Kim et al., 2007).

Estimates suggest that, by upgrading the drainage system in Mumbai, losses associated with a 1-in-100 year flood event today could be reduced by as much as 70% and, through extending insurance to 100% penetration, the indirect effects of flooding could be almost halved, speeding recovery significantly (Ranger et al., 2011). On the east coast of India, clusters of districts with poor infrastructure and demographic development are also the regions of maximum vulnerability. Hence, extreme events are expected to be more catastrophic in nature for the people living in these districts. Moreover, the lower the district is in terms of the infrastructure index and its growth, the more vulnerable it is to the potential damage from extreme events and hence people living in these regions are prone to be highly vulnerable (Patnaik and Narayanan, 2009). In 2008, the embankments on the Kosi River (a tributary of the Ganges) failed, displacing more than 60,000 people in Nepal and 3.5 million in India. Transport and power systems were disrupted across large areas. However, the embankment failure was not caused by an extreme event but represented a failure of interlinked physical and institutional infrastructure systems in an area characterized by complex social, political, and environmental relationships (Moench, 2010).

24.4.5.4. Vulnerabilities to Key Drivers

Disruption of basic services such as water supply, sanitation, energy provision, and transportation systems have implications for local economies and “strip populations of their assets and livelihoods,” in some cases leading to mass migration (UN-HABITAT, 2010). Such impacts are not expected to be evenly spread among regions and cities, across sectors of the economy, or among socioeconomic groups. They tend to reinforce existing inequalities and disrupt the social fabric of cities and exacerbate poverty.

24.4.5.5. Adaptation Options

An ADB and UN report estimates that “about two-thirds of the \$8 trillion needed for infrastructure investment in Asia and the Pacific between 2010 and 2020 will be in the form of new infrastructure, which creates tremendous opportunities to design, finance and manage more sustainable infrastructure” (UN ESCAP et al., 2012, p. 18). Adaptation measures that offer a “no regrets” solution are proposed for developing countries, “where basic urban infrastructure is often absent (e.g., appropriate drainage infrastructure), leaving room for actions that both increase immediate well-being and reduce vulnerability to future climate change” (Hallegatte and Corfee-Morlot, 2011). The role of urban planning and urban planners in adaptation to climate change impacts has been emphasized (Fuchs et al., 2011; IPCC, 2012; Tyler and Moench, 2012). The focus on solely adapting through physical infrastructure in urban areas requires complementary adaptation planning, management,

Frequently Asked Questions

FAQ 24.3 | Who is most at risk from climate change in Asia?

People living in low-lying coastal zones and flood plains are probably most at risk from climate change impacts in Asia. Half of Asia’s urban population lives in these areas. Compounding the risk for coastal communities, Asia has more than 90% of the global population exposed to tropical cyclones. The impact of such storms, even if their frequency or severity remains the same, is magnified for low-lying and coastal zone communities because of rising sea level (*medium confidence*). Vulnerability of many island populations is also increasing due to climate change impacts. Settlements on unstable slopes or landslide-prone areas, common in some parts of Asia, face increased likelihood of rainfall-induced landslides.

Asia is predominantly agrarian, with 58% of its population living in rural areas, of which 81% are dependent on agriculture for their livelihoods. Rural poverty in parts of Asia could be exacerbated due to negative impacts from climate change on rice production, and a general increase in food prices and the cost of living (*high confidence*).

Climate change will have widespread and diverse health impacts. More frequent and intense heat waves will increase mortality and morbidity in vulnerable groups in urban areas (*high confidence*). The transmission of infectious disease, such as cholera epidemics in coastal Bangladesh, and schistosomiasis in inland lakes in China, and diarrheal outbreaks in rural children will be affected as a result of warmer air and water temperatures and altered rain patterns and water flows (*medium confidence*). Outbreaks of vaccine-preventable Japanese encephalitis in the Himalayan region and malaria in India and Nepal have been linked to rainfall. Changes in the geographical distribution of vector-borne diseases, as vector species that carry and transmit diseases migrate to more hospitable environments, will occur (*medium confidence*). These effects will be most noted close to the edges of the current habitats of these species.

governance, and institutional arrangements to be able to deal with the uncertainty and unprecedented challenges implied by climate change (Revi, 2008; Birkmann et al., 2010; Garschagen and Kraas, 2011).

24.4.6. Human Health, Security, Livelihoods, and Poverty

24.4.6.1. Sub-regional Diversity

Although rapidly urbanizing, Asia is still predominantly an agrarian society, with 57.28% of its total population living in rural areas, of which 81.02% are dependent on agriculture for their livelihoods (FAOSTAT, 2011). Rural poverty is higher than urban poverty, reflecting the heavy dependence on natural resources that are directly influenced by changes in weather and climate (Haggblade et al., 2010; IFAD, 2010). Rural poverty is expected to remain more prevalent than urban poverty for decades to come (Ravallion et al., 2007). However, climate change will also affect urbanizing Asia, where the urban poor will be impacted indirectly, as evident from the food price rises in the Middle East and other areas in 2007–2008. Certain categories of urban dwellers, such as urban wage labor households, are particularly vulnerable (Hertel et al., 2010).

Agriculture has been identified as a key driver of economic growth in Asia (World Bank, 2007). Although economic growth was impressive in recent decades, there are still gaps in development compared to the rest of the world (World Bank, 2011). Southeast Asia is the third poorest performing region after sub-Saharan Africa and southern Asia in terms of the Human Development Indicators (UN DESA Statistics Division, 2009). Impacts on human security in Asia will manifest primarily through impacts on water resources, agriculture, coastal areas, resource-dependent livelihoods, and urban settlements and infrastructure, with implications for human health and well-being. Regional disparities on account of socioeconomic context and geographical characteristics largely define the differential vulnerabilities and impacts within countries in Asia (Thomas, 2008; Sivakumar and Stefanski, 2011).

24.4.6.2. Observed Impacts

24.4.6.2.1. Floods and health

Epidemics have been reported after floods and storms (Bagchi, 2007) as a result of decreased drinking water quality (Harris et al., 2008; Hashizume et al., 2008; Solberg, 2010; Kazama et al., 2012), mosquito proliferation (Pawar et al., 2008), and exposure to rodent-borne pathogens (Kawaguchi et al., 2008; Zhou et al., 2011) and the intermediate snail hosts of *Schistosoma* (Wu et al., 2008).

Contaminated urban flood waters have caused exposure to pathogens and toxic compounds, for example, in India and Pakistan (Sohan et al., 2008; Warraich et al., 2011).

Mental disorders and posttraumatic stress syndrome have also been observed in disaster-prone areas (Udomratn, 2008) and, in India, have been linked to age and gender (Telles et al., 2009). See also Section 11.4.2 for flood-attributable deaths.

24.4.6.2.2. Heat and health

The effects of heat on mortality and morbidity have been studied in many countries, with a focus on the elderly and people with cardiovascular and respiratory disorders (Kan et al., 2007; Guo et al., 2009; Huang et al., 2010). Associations between high temperatures and mortality have been shown for populations in India and Thailand (McMichael et al., 2008) and in several cities in East Asia (Kim et al., 2006; Chung et al., 2009). Several studies have analyzed the health effects of air pollution in combination with increased temperatures (Lee et al., 2007; Qian et al., 2010; Wong et al., 2010; Yi et al., 2010). Intense heat waves have been shown to affect outdoor workers in South Asia (Nag et al., 2007; Hyatt et al., 2010).

24.4.6.2.3. Drought and health

Dust storms in Southwest, Central, and East Asia result in increased hospital admissions and worsen asthmatic conditions, as well as causing skin and eye irritations (Griffin, 2007; Hashizume et al., 2010; Kan et al., 2012). Droughts may also lead to wildfires and smoke exposure, with increased morbidity and mortality, as observed in Southeast Asia (Johnston et al., 2012). Drought can also disrupt food security, increasing malnutrition (Kumar et al., 2005) and thus susceptibility to infectious diseases.

24.4.6.2.4. Water-borne diseases

Many pathogens and parasites multiply faster at higher temperatures. Temperature increases have been correlated with increased incidence of diarrheal diseases in East Asia (Huang et al., 2008; Zhang et al., 2008; Onozuka et al., 2010). Other studies from South and East Asia have shown an association between increased incidence of diarrhea and higher temperatures and heavy rainfall (Hashizume et al., 2007; Chou et al., 2010). Increasing coastal water temperatures correlated with outbreaks of systemic *Vibrio vulnificus* infection in Israel (Paz et al., 2007) and South Korea (Kim and Jang, 2010). Cholera outbreaks in coastal populations in South Asia have been associated with increased water temperatures and algal blooms (Huq et al., 2005). The El Niño–Southern Oscillation (ENSO) cycle and Indian Ocean Dipole have been associated with cholera epidemics in Bangladesh (Pascual et al., 2000; Rodó et al., 2002; Hashizume et al., 2011).

24.4.6.2.5. Vector-borne diseases

Increasing temperatures affect vector-borne pathogens during the extrinsic incubation period and shorten vector life-cycles, facilitating larger vector populations and enhanced disease transmission, while the vector's ability to acquire and maintain a pathogen tails off (Paijmans et al., 2012). Dengue outbreaks in South and Southeast Asia are correlated with temperature and rainfall with varying time lags (Su, 2008; Hii et al., 2009; Hsieh and Chen, 2009; Shang et al., 2010; Sriptom et al., 2010; Hashizume et al., 2012). Outbreaks of vaccine-preventable Japanese encephalitis have been linked to rainfall in studies from the Himalayan region (Partridge et al., 2007; Bhattachan et al., 2009), and to rainfall

and temperature in South and East Asia (Bi et al., 2007; Murty et al., 2010). Malaria prevalence is often influenced by non-climate variability factors, but studies from India and Nepal have found correlations with rainfall (Devi and Jauhari, 2006; Dev and Dash, 2007; Dahal, 2008; Laneri et al., 2010). Temperature was linked to distribution and seasonality of malaria mosquitoes in Saudi Arabia (Kheir et al., 2010). The reemergence of malaria in central China has been attributed to rainfall and increases in temperature close to water bodies (Zhou et al., 2010). In China, temperature, precipitation, and the virus-carrying index among rodents have been found to correlate with the prevalence of hemorrhagic fever with renal syndrome (Guan et al., 2009).

24.4.6.2.6. Livelihoods and poverty

An estimated 51% of total income in rural Asia comes from non-farm sources (Hagglade et al., 2009, 2010), mostly local non-farm business and employment. The contribution of remittances to rural income has grown steadily (Estudillo and Otsuka, 2010). Significant improvements have been made in poverty eradication over the past decade (World Bank, 2007), with rapid reductions in poverty in East Asia, followed by South Asia (IFAD, 2010). A significant part of the reduction has come from population shifts, rapid growth in agriculture, and urban contributions (Janvry and Sadoulet, 2010). Climate change negatively impacts livelihoods (see Table SM24-4) and these impacts are directly related to natural resources affected by changes in weather and climate. Factors that have made agriculture less sustainable in the past include input non-responsive yields, soil erosion, natural calamities, and water and land quality related problems (Dev, 2011). These have predisposed rural livelihoods to climate change vulnerability. Livelihoods are impacted by droughts (Selvaraju et al., 2006; Harshita, 2013), floods (Nguyen, 2007; Keskinen et al., 2010; Nuorteva et al., 2010; Dun, 2011), and typhoons (Huigen and Jens, 2006; Gaillard et al., 2007; Uy et al., 2011). Drought disproportionately impacts small farmers, agricultural laborers, and small businessmen (Selvaraju et al., 2006), who also have least access to rural safety net mechanisms, including financial services (IFAD, 2010), despite recent developments in microfinance services in parts of Asia. Past floods have exposed conditions such as lack of access to alternative livelihoods, difficulty in maintaining existing livelihoods, and household debts leading to migration in the Mekong region (Dun, 2011). Similar impacts of repeated floods leading to perpetual vulnerability were found in the Tonle Sap Lake area of Cambodia (Nuorteva et al., 2010; Keskinen et al., 2010). Typhoon impacts are mainly through damage to the livelihood assets of coastal populations in the Philippines and the level of ownership of livelihood assets has been a major determinant of vulnerability (Uy et al., 2011).

24.4.6.3. Projected Impacts

24.4.6.3.1. Health effects

An emerging public health concern in Asia is increasing mortality and morbidity due to heat waves. An aging population will increase the number of people at risk, especially those with cardiovascular and respiratory disorders. Urban heat island effects have increased (Tan et al., 2010), although local adaptation of the built environment and urban

planning will determine the impacts on public health. Heat stress disorders among workers and consequent productivity losses have also been reported (Lin et al., 2009; Langkulsen et al., 2010). The relationship between temperature and mortality is often U-shaped (Guo et al., 2009), with increased mortality also during cold events, particularly in rural environments, even if temperatures do not fall below 0°C (Hashizume et al., 2009). However, some studies in developing areas suggest that factors other than climate can be important, so warming may not decrease cold-related deaths much in these regions (Honda and Ono, 2009).

Climate change will affect the local transmission of many climate-sensitive diseases. Increases in heavy rain and temperature are projected to increase the risk of diarrheal diseases in, for example, China (Zhang et al., 2008). However, the impact of climate change on malaria risk will differ between areas, as projected for West and South Asia (Husain and Chaudhary, 2008; Garg et al., 2009; Majra and Gur, 2009), while a study suggested that the impact of socioeconomic development will be larger than that of climate change (Béguin et al., 2011).

Climate change is also expected to affect the spatiotemporal distribution of dengue fever in the region, although the level of evidence differs across geographical locations (Banu et al., 2011). Some studies have developed climate change-disease prevalence models; for example, one for schistosomiasis in China shows an increased northern distribution of the disease with climate change (Zhou et al., 2008; Kan et al., 2012). Impacts of climate change on fish production (Qiu et al., 2010) are being studied, along with impacts on chemical pathways in the marine environment and consequent impacts on food safety (Tirado et al., 2010), including seafood safety (Marques et al., 2010).

24.4.6.3.2. Livelihood and poverty

Floods, droughts, and changes in seasonal rainfall patterns are expected to negatively impact crop yields, food security, and livelihoods in vulnerable areas (Dawe et al., 2008; Kelkar et al., 2008; Douglas, 2009). Rural poverty in parts of Asia could be exacerbated (Skoufias et al., 2011) as a result of impacts on the rice crop and increases in food prices and the cost of living (Hertel et al., 2010; Rosegrant, 2011). The poverty impacts of climate change will be heterogeneous among countries and social groups (see Table SM24-5). In a low crop productivity scenario, producers in food exporting countries, such as Indonesia, the Philippines, and Thailand, would benefit from global food price rises and reduce poverty, while countries such as Bangladesh would experience a net increase in poverty of approximately 15% by 2030 (Hertel et al., 2010). These impacts will also differ within food exporting countries, with disproportionate negative impacts on farm laborers and the urban poor. Skoufias et al. (2011) project significant negative impacts of a rainfall shortfall on the welfare of rice farmers in Indonesia, compared to a delay in rainfall onset. These impacts may lead to global mass migration and related conflicts (Laczko and Aghazarm, 2009; Barnett and Webber, 2010; Warner, 2010; World Bank, 2010).

In North Asia, climate-driven changes in tundra and forest-tundra biomes may influence indigenous peoples who depend on nomadic tundra pastoralism, fishing, and hunting (Kumpula et al., 2011).

24.4.6.4. Vulnerabilities to Key Drivers

Key vulnerabilities vary widely within the region. Climate change can exacerbate current socioeconomic and political disparities and add to the vulnerability of Southeast Asia and Central Asia to security threats that may be transnational in nature (Jasparro and Taylor, 2008; Lioubimtseva and Henebry, 2009). Apart from detrimental impacts of extreme events, vulnerability of livelihoods in agrarian communities also arises from geographic settings, demographic trends, socioeconomic factors, access to resources and markets, unsustainable water consumption, farming practices, and lack of adaptive capacity (Acosta-Michlik and Espaldon, 2008; Allison et al., 2009; Byg and Salick, 2009; Lioubimtseva and Henebry, 2009; Salick and Ross, 2009; Salick et al., 2009; UN DESA Statistics Division, 2009; Xu et al., 2009; Knox et al., 2011; Mulligan et al., 2011). Urban wage laborers were found to be more vulnerable to cost of living related poverty impacts of climate change than those who directly depend on agriculture for their livelihoods (Hertel et al., 2010). In Indonesia, drought-associated fires increase vulnerability of agriculture, forestry, and human settlements, particularly in peatland areas (Murdiyarso and Lebel, 2007). Human health is also a major area of focus for Asia (Munslow and O'Dempsey, 2010), where the magnitude and type of health effects from climate change depend on differences in socioeconomic and demographic factors, health systems, the natural and built environment, land use changes, and migration, in relation to local resilience and adaptive capacity. The role of institutions is also critical, particularly in influencing vulnerabilities arising from gender (Ahmed and Fajber, 2009), caste and ethnic differences (Jones and Boyd, 2011), and securing climate-sensitive livelihoods in rural areas (Agrawal and Perrin, 2008).

24.4.6.5. Adaptation Options

Disaster preparedness on a local community level could include a combination of indigenous coping strategies, early-warning systems, and adaptive measures (Paul and Routray, 2010). Heat warning systems have been successful in preventing deaths among risk groups in Shanghai (Tan et al., 2007). New work practices to avoid heat stress among outdoor workers in Japan and the United Arab Emirates have also been successful (Morioka et al., 2006; Joubert et al., 2011). Early warning models have been developed for haze exposure from wildfires, in, for example, Thailand (Kim Oanh and Leelasakultum, 2011), and are being tested in infectious disease prevention and vector control programs, as for malaria in Bhutan (Wangdi et al., 2010) and Iran (Haghdoost et al., 2008), or are being developed, as for dengue fever region-wide (Wilder-Smith et al., 2012).

Some adaptation practices provide unexpected livelihood benefits, as with the introduction of traditional flood mitigation measures in China, which could positively impact local livelihoods, leading to reductions in both the physical and economic vulnerabilities of communities (Yu et al., 2009). A greater role of local communities in decision making is also proposed (Alauddin and Quiggin, 2008) and in prioritization and adoption of adaptation options (Prabhakar et al., 2010; Prabhakar and Srinivasan, 2011). Defining adequate community property rights, reducing income disparity, exploring market-based and off-farm livelihood options, moving from production-based approaches to productivity and efficiency decision-making based approaches, and promoting integrated decision-making

approaches have also been suggested (Merrey et al., 2005; Brouwer et al., 2007; Paul et al., 2009; Niino, 2011; Stucki and Smith, 2011).

Climate-resilient livelihoods can be fostered through the creation of bundles of capitals (natural, physical, human, financial, and social capital) and poverty eradication (Table SM24-8). Greater emphasis on agricultural growth has been suggested as an effective means of reducing rural poverty (Janvry and Sadoulet, 2010; Rosegrant, 2011). Bundled approaches are known to facilitate better adaptation than individual adaptation options (Acosta-Michlik and Espaldon, 2008; Fleischer et al., 2011). Community-based approaches have been suggested to identify adaptation options that address poverty and livelihoods, as these techniques help capture information at the grassroots (Huq and Reid, 2007; van Aalst et al., 2008), and help integration of disaster risk reduction, development, and climate change adaptation (Heltberg et al., 2010), connect local communities and outsiders (van Aalst et al., 2008), address the location-specific nature of adaptation (Iwasaki et al., 2009; Rosegrant, 2011), help facilitate community learning processes (Baas and Ramasamy, 2008), and help design location-specific solutions (Ensor and Berger, 2009). Some groups can become more vulnerable to change after being "locked into" specialized livelihood patterns, as with fish farmers in India (Coulthard, 2008).

Livelihood diversification, including livelihood assets and skills, has been suggested as an important adaptation option for buffering climate change impacts on certain kinds of livelihoods (Selvaraju et al., 2006; Nguyen, 2007; Agrawal and Perrin, 2008; IFAD, 2010; Keskinen et al., 2010; Uy et al., 2011). The diversification should occur across assets, including productive assets, consumption strategies, and employment opportunities (Agrawal and Perrin, 2008). Ecosystem-based adaptation has been suggested to secure livelihoods in the face of climate change (Jones et al., 2012), integrating the use of biodiversity and ecosystem services into an overall strategy to help people adapt (IUCN, 2009). Among financial means, low-risk liquidity options such as microfinance programs and risk transfer products can help lift the rural poor from poverty and accumulate assets (Barrett et al., 2007; Jarvis et al., 2011).

24.4.7. Valuation of Impacts and Adaptation

Economic valuation in Asia generally covers impacts and vulnerabilities of diverse sectors such as food production, water resources, and human health (Aydinalp and Cresser, 2008; Kelkar et al., 2008; Lioubimtseva and Henebry, 2009; Su et al., 2009; Srivastava et al., 2010). Multi-sector evaluation that unpacks the relationships between and across sectors, particularly in a context of resource scarcity and competition, is very limited. Information is scarce especially for North, Central, and West Asia.

Generally, annual losses from drought are expected to increase based on various projections under diverse scenarios, but such losses are expected to be reduced if adaptation measures are implemented (ADB, 2009; Sutton et al., 2013). It is also stressed that there are great uncertainties associated with the economic aspects of climate change. In China, the total loss due to drought projected in 2030 is expected to range from US\$1.1 to 1.7 billion for regions in northeast China and about US\$0.9 billion for regions in north China (ECA, 2009), with adaptation

measures having the potential to avert half of the losses. In India, the estimated countrywide agricultural loss in 2030—more than US\$7 billion, which will severely affect the income of 10% of the population—could be reduced by 80% if cost-effective climate resilience measures are implemented (ECA, 2009).

In Indonesia, the Philippines, Thailand, and Vietnam, under the A2 scenario, the Policy Analysis for the Greenhouse Effect 2002 (PAGE2002) integrated assessment model projects a mean loss of 2.2% of GDP by 2100 on an annual basis, if only the market impact (mainly related to agriculture and coastal zones) is considered (ADB, 2009). This is well above the world's projected mean GDP loss of 0.6% each year by 2100 due to market impact alone. In addition, the mean cost for the four countries could reach 5.7% of GDP if non-market impacts related to health and ecosystems are included and 6.7% of GDP if catastrophic risks are also taken into account. The cost of adaptation for agriculture and coastal zones is expected to be about US\$5 billion per year by 2020 on average. Adaptation that is complemented with global mitigation measures is expected to be more effective in reducing the impacts of climate change (IPCC, 2007; ADB, 2009; UNFCCC, 2009; MNRE, 2010; Begum et al., 2011).

24.5. Adaptation and Managing Risks

24.5.1. Conservation of Natural Resources

Natural resources are already under severe pressure from land use change and other impacts in much of Asia. Deforestation in Southeast Asia has received most attention (Sodhi et al., 2010; Miettinen et al., 2011a), but ecosystem degradation, with the resulting loss of natural goods and services, is also a major problem in other ecosystems. Land use change is also a major source of regional greenhouse gas emissions, particularly in Southeast Asia (see WGI AR5 Section 6.3.2.2, Table 6.3). Projected climate change is expected to intensify these pressures in many areas (see Sections 24.4.2.3, 24.4.3.3), most clearly for coral reefs, where increases in sea surface temperature and ocean acidification are a threat to all reefs in the region and the millions of people who depend on them (see Section 5.4.2.4; Boxes CC-CR, CC-OA). Adaptation has so far focused on minimizing non-climate pressures on natural resources and restoring connectivity to allow movements of genes and species between fragmented populations (see Section 24.4.2.5). Authors have also suggested a need to identify and protect areas that will be subject to the least damaging climate change ("climate refugia") and to identify additions to the protected area network that will allow for expected range shifts, for example, by extending protection to higher altitudes or latitudes. Beyond the intrinsic value of wild species and ecosystems, ecosystem-based approaches to adaptation aim to use the resilience of natural systems to buffer human systems against climate change, with potential social, economic, and cultural co-benefits for local communities (see Box CC-EA).

24.5.2. Flood Risks and Coastal Inundation

Many coasts in Asia are exposed to threats from floods and coastal inundation (see also Section 24.4.5.3). Responding to a large number

of climate change impact studies for each Asian country over the past decade (e.g., Karim and Mimura, 2008; Pal and Al-Tabbaa, 2009), various downscaled tools to support, formulate, and implement climate change adaptation policy for local governments are under development. One of the major tools is vulnerability assessment and policy option identification with Geographical Information Systems (GIS). These tools are expected to be of assistance in assessing city-specific adaptation options by examining estimated impacts and identified vulnerability for some coastal cities and areas in Asian countries (e.g., Brouwer et al., 2007; Taylor, 2011; Storch and Downes, 2011). These tools and systems sometimes take the form of integration of top-down approaches and bottom-up (community-based) approaches (see Section 14.5). Whereas top-down approaches give scientific knowledge to local actors, community-based approaches are built on existing knowledge and expertise to strengthen coping and adaptive capacity by involving local actors (van Aalst et al., 2008). Community-based approaches may have a limitation in that they place greater responsibility on the shoulders of local people without necessarily increasing their capacity proportionately (Allen, 2006). As the nature of adaptive capacity varies depending on the formulation of social capital and institutional context in the local community, it is essential for the approaches to be based on an understanding of local community structures (Adger, 2003).

24.5.3. Economic Growth and Equitable Development

Climate change challenges fundamental elements in social and economic policy goals such as prosperity, growth, equity, and sustainable development (Mearns and Norton, 2010). Economic, social, and environmental equity is an enduring challenge in many parts of Asia. Generally, the level of wealth (typically GDP) has been used as a measure of human vulnerability of a country but this approach has serious limitations (Dellink et al., 2009; Mattoo and Subramanian, 2012). In many cases, social capital—an indicator of equity in income distribution within countries—is a more important factor in vulnerability and resilience than GDP per capita (Islam et al., 2006; Lioubimtseva and Henebry, 2009). Furthermore, political and institutional instabilities can undermine the influence of economic development (Lioubimtseva and Henebry, 2009). Poor and vulnerable countries are at greater risk of inequity and loss of livelihoods from the impacts of climate extremes as their options for coping with such events are limited. Many factors contribute to this limitation, including poverty, illiteracy, weak institutions and infrastructures, poor access to resources, information and technology, poor health care, and low investment and management capabilities. The overexploitation of land resources including forests, increases in population, desertification, and land degradation pose additional threats (UNDP, 2006). This is particularly true for developing countries in Asia with a high level of natural resource dependency. Provision of adequate resources based on the burden sharing and the equity principle will serve to strengthen appropriate adaptation policies and measures in such countries (Su et al., 2009).

24.5.4. Mainstreaming and Institutional Barriers

Mainstreaming climate change adaptation into sustainable development policies offers a potential opportunity for good practice to build resilience and reduce vulnerability, depending on effective, equitable,

and legitimate actions to overcome barriers and limits to adaptation (ADB, 2005; Lim et al., 2005; Lioubimtseva and Henebry, 2009). The level of adaptation mainstreaming is most advanced in the context of official development assistance, where donor agencies and international financial institutions have made significant steps toward taking climate change adaptation into account in their loan and grant making processes (Gigli and Agrawala, 2007; Klein et al., 2007). Although some practical experiences of adaptation in Asia at the regional, national, and local level are emerging, there can be barriers that impede or limit adaptation. These include challenges related to competing national priorities, awareness and capacity, financial resources for adaptation implementation, institutional barriers, biophysical limits to ecosystem adaptation, and social and cultural factors (Lasco et al., 2009, 2012; Moser and Ekstrom, 2010). Issues with resource availability might not only result from climate change, but also from weak governance mechanisms and the breakdown of policy and regulatory structures, especially with common-pool resources (Moser and Ekstrom, 2010). Furthermore, the impact of climate change depends on the inherent vulnerability of the socio-ecological systems in a region as much as on the magnitude of the change (Evans, 2010). Recent studies linking climate-related resource scarcities and conflict call for enhanced regional cooperation (Gautam, 2012).

24.5.5. Role of Higher Education in Adaptation and Risk Management

To enhance the development of young professionals in the field of climate change adaptation, the topic could be included in higher education, especially in formal education programs. Shaw et al. (2011) mentioned that higher education in adaptation and disaster risk reduction in the Asia-Pacific region can be done through environment disaster linkage, focus on hydro-meteorological disasters, and emphasizing synergy issues between adaptation and risk reduction. Similar issues are also highlighted by other authors (Chhokar, 2010; Niu et al., 2010; Nomura and Abe, 2010; Ryan et al., 2010). Higher education should be done through lectures and course work, field studies, internships, and establishing the education-research link by exposing students to field realities. In this regard, guiding principles could include an inclusive curriculum, focus on basic theory, field orientation, multidisciplinary courses, and practical skill enhancement. Bilateral or multilateral practical research programs on adaptation and risk management by graduate students and young faculty members would expose them to real field problems.

24.6. Adaptation and Mitigation Interactions

Integrated mitigation and adaptation responses focus on either land use changes or technology development and use. Changes in land use, such as agroforestry, may provide both mitigation and adaptation benefits (Verchot et al., 2007), or otherwise, depending on how they are implemented. Agroforestry practices provide carbon storage and may decrease soil erosion, increase resilience against floods, landslides, and drought, increase soil organic matter, reduce the financial impact of crop failure, as well as have biodiversity benefits over other forms of agriculture, as shown, for example, in Indonesia (Clough et al., 2011).

Integrated approaches are often needed when developing mitigation-adaptation synergies, as seen in waste-to-compost projects in Bangladesh (Ayers and Huq, 2009). Other adaptation measures that increase biomass and/or soil carbon content, such as ecosystem protection and reforestation, will also contribute to climate mitigation by carbon sequestration. However, exotic monocultures may fix more carbon than native mixtures while supporting less biodiversity and contributing less to ecological services, calling for compromises that favor biodiversity-rich carbon storage (Diaz et al., 2009). The potential for both adaptation and mitigation through forest restoration is greatest in the tropics (Sasaki et al., 2011). At higher latitudes (>45°N), reforestation can have a net warming influence by reducing surface albedo (Anderson-Teixeira et al., 2012). Expansion of biofuel crops on abandoned and marginal agricultural lands could potentially make a large contribution to mitigation of carbon emissions from fossil fuels, but could also have large negative consequences for both carbon and biodiversity if it results directly or indirectly in the conversion of carbon-rich ecosystems to cropland (Fargione et al., 2010; Qin et al., 2011). Mechanisms, such as Reduction of Emissions from Deforestation and Forest Degradation (REDD+), that put an economic price on land use emissions, could reduce the risks of such negative consequences (Thomson et al., 2010), but the incentive structures need to be worked out very carefully (Busch et al., 2012).

Forests and their management are also often emphasized for providing resilient livelihoods and reducing poverty (Chhatre and Agrawal, 2009; Noordwijk, 2010; Persha et al., 2010; Larson, 2011). Securing rights to resources is essential for greater livelihood benefits for poor indigenous and traditional people (Macchi et al., 2008) and the need for REDD+ schemes to respect and promote community forest tenure rights has been emphasized (Angelsen, 2009). It has been suggested that indigenous people can provide a bridge between biodiversity protection and climate change adaptation (Salick and Ross, 2009): a point that appears to be missing in the current discourse on ecosystem-based adaptation. There are arguments against REDD+ supporting poverty reduction due to its inability to promote productive use of forests, which may keep communities in perpetual poverty (Campbell, 2009), but there is a contrasting view that REDD+ can work in forests managed for timber production (Guariguata et al., 2008; Putz et al., 2012), especially through reduced impact logging (Guariguata et al., 2008) and other approaches such as assuring the legality of forest products, certifying responsible management, and devolving control over forests to empowered local communities (Putz et al., 2012).

On rivers and coasts, the use of hard defenses (e.g., channelization, sea walls, bunds, dams) to protect agriculture and human settlements from flooding may have negative consequences for both natural ecosystems and carbon sequestration by preventing natural adjustments to changing conditions (see Section 24.4.3.5). Conversely, setting aside landward buffer zones along coasts and rivers would be positive for both. The very high carbon sequestration potential of the organic-rich soils in mangroves (Donato et al., 2011) and peat swamp forests (Page et al., 2011) provides opportunities for combining adaptation with mitigation through restoration of degraded areas.

Mitigation measures can also result in public health benefits (Bogner et al., 2008; Haines et al., 2009). For example, sustainable cities with fewer

fossil fuel-driven vehicles (mitigation) and more trees and greenery (carbon storage and adaptation to the urban heat island effect) would have a number of co-benefits, including public health—a promising strategy for “triple win” interventions (Romero-Lankao et al., 2011). Other examples include efforts to decarbonize electricity production in India and China that are projected to decrease mortality due to reduced particulate matter with aerodynamic diameter $<5 \mu\text{m}$ (PM_{10}) and $<2.5 \mu\text{m}$ ($\text{PM}_{2.5}$) (Markandya et al., 2009); policies to increase public transportation, promote walking and cycling, and reduce private cars that will increase air quality and decrease the health burden, particularly in urban environments as projected in India (Woodcock et al., 2009); and abandoning the use of biomass fuel or coal for indoor cooking and heating to improve indoor air quality and respiratory and cardiac health among, in particular, women and children in India and China (Wilkinson et al., 2009). Conversely, actions to reduce current environmental-public health issues may often have beneficial mitigation effects, like traffic emissions reduction programs in China (Wu et al., 2011) and India (Reynolds and Kandikar, 2008).

24.7. Intra-regional and Inter-regional Issues

24.7.1. Transboundary Pollution

Many Asian countries and regions face long-distance and transboundary air pollution problems. In eastern China, Japan, and the Korean Peninsula, these include dust storms that originate in the arid and semiarid regions upwind, with impacts on climate, human health, and ecosystems (Huang et al., 2013). The susceptibility of the land surface to wind erosion is strongly influenced by vegetation cover, which is in turn sensitive to climate change and other human impacts. In the humid tropics of Southeast Asia, in contrast, the major transboundary pollution issue involves smoke aerosols from burning of biomass and peatlands, mostly during clearance for agriculture (Miettinen et al., 2011b; Gautam et al., 2013). Apart from the large impact on human health, these aerosols may be having a significant effect on rainfall in equatorial regions, leading to the possibility of climate feedbacks, with fires reducing rainfall and promoting further fires (Tosca et al., 2012).

Pollutants of industrial origin are also a huge problem in many parts of the region, with well-documented impacts on human health (Section 24.4.6) and the climate (see WGI AR5 Chapters 7, 8).

24.7.2. Trade and Economy

The ASEAN Free Trade Agreement (AFTA) and the Indonesia-Japan Economic Partnership Agreement (IJEPA) have positively impacted the Indonesian economy and reduced water pollution, but increased CO_2 emissions by 0.46% compared to the business-as-usual situation, mainly due to large emission increases in the transportation sector (Gumilang et al., 2011). Full liberalization of tariffs and GDP growth concentrated in China and India have led to transport emissions growing much faster than the value of trade, as result of a shift toward distant trading partners (Cristea et al., 2013). China’s high economic growth and flourishing domestic and international trade has resulted in increased consumption and pollution of water resources (Guan and Hubacek, 2007). Japanese

imports from the ASEAN region are negatively correlated with per capita carbon emissions (Atici, 2012) owing to strict regulations in Japan that prevent import from polluting sectors. Export-led growth is central to the economic progress and well-being of Southeast Asian countries. Generally, as exports rise, carbon emissions tend to rise. International trading systems that help address the challenge of climate change need further investigation.

24.7.3. Migration and Population Displacement

Floods and droughts are predominant causes for internal displacement (IDMC, 2011). In 2010 alone, 38.3 million people were internally displaced: 85% because of hydrological hazards and 77% in Asia. Floods are increasingly playing a role in migration in the Mekong Delta (Warner, 2010). Often some migrants return to the vulnerable areas (Piguet, 2008) giving rise to ownership, rights of use, and other issues (Kolmannskog, 2008). Increasing migration has led to increasing migration-induced remittances contributing to Asian economies, but has had negligible effect on the poverty rate (Vargas-Silva et al., 2009). In Bangladesh, migrant workers live and work under poor conditions, such as crowded shelters, inadequate sanitation, conflict and competition with the local population, and exploitation (Penning-Rowsell et al., 2011). Forced migration can result from adaptation options such as construction of dams, but the negative outcomes could be allayed by putting proper safeguards in place (Penning-Rowsell et al., 2011). Managed retreat of coastal communities is a suggested option to address projected sea level rise (Alexander et al., 2012). A favorable approach to deal with migration is within a development framework and through adaptation strategies (Penning-Rowsell et al., 2011; ADB, 2012).

24.8. Research and Data Gaps

Studies of observed climate changes and their impacts are still inadequate for many areas, particularly in North, Central, and West Asia (Table 24-2). Improved projections for precipitation, and thus water supply, are most urgently needed. Another priority is developing water management strategies for adaptation to changes in demand and supply. More research is also needed on the health effects of changes in water quality and quantity. Understanding of climate change impacts on ecosystems and biodiversity in Asia is currently limited by the poor quality and low accessibility of biodiversity information (UNEP, 2012). National biodiversity inventories are incomplete and few sites have the baseline information needed to identify changes. For the tropics, major research gaps include the temperature dependence of carbon fixation by tropical trees, the thermal tolerances and acclimation capacities of both plants and animals, and the direct impacts of rising CO_2 (Corlett, 2011; Zuidema et al., 2013). Rising CO_2 is also expected to be important in cool-arid ecosystems, where lack of experimental studies currently limits ability to make predictions (Poulter et al., 2013). Boreal forest dynamics will be influenced by complex interactions between rising temperatures and CO_2 , permafrost thawing, forest fires, and insect outbreaks (Osawa et al., 2010; Zhang et al., 2011), and understanding this complexity will require enhanced monitoring of biodiversity and species ranges, improved modeling, and greater knowledge of species biology (Meleshko and Semenov, 2008).

Rice is the most studied crop but there are still significant uncertainties in model accuracy, CO₂-fertilization effects, and regional differences (Masutomi et al., 2009; Zhang et al., 2010; Shuang-He et al., 2011). For other crops, there is even greater uncertainty. Studies are also needed of the health effects of interactions between heat and air pollution in urban and rural environments.

More generally, research is needed on impacts, vulnerability, and adaptation in urban settlements, especially cities with populations of less than 500,000, which share half the region's urban population. Greater understanding is required of the linkages between local livelihoods, ecosystem functions, and land resources for creating a positive impact

on livelihoods in areas with greater dependence on natural resources (Paul et al., 2009). Increasing regional collaboration in scientific research and policy making has been suggested for reducing climate change impacts on water, biodiversity, and livelihoods in the Himalayan region (Xu et al., 2009) and could be considered elsewhere. The literature suggests that work must begin now on building understanding of the impacts of climate change and moving forward with the most cost-effective adaptation measures (ADB, 2007; Cai et al., 2008; Stage, 2010).

For devising mitigation policies, the key information needed is again the most cost-effective measures (Nguyen, 2007; Cai et al., 2008; Mathy and Guivarch, 2010).

Table 24-2 | The amount of information supporting conclusions regarding observed and projected impacts in Asia.

Sector	Topics/issues O = Observed impacts, P = Projected Impacts	North Asia		East Asia		Southeast Asia		South Asia		Central Asia		West Asia	
		O	P	O	P	O	P	O	P	O	P	O	P
Freshwater resources	Major river runoff	/	x	/	/	/	/	/	x	x	x	x	x
	Water supply	x	x	x	x	x	x	x	x	x	x	x	x
Terrestrial and inland water systems	Phenology and growth rates	/	/	/	/	x	x	x	x	x	x	x	x
	Distributions of species and biomes	/	/	/	/	x	x	x	/	x	x	x	x
	Permafrost	/	/	/	/	/	x	/	/	/	/	/	x
	Inland waters	x	x	/	x	x	x	x	x	x	x	x	x
Coastal systems and low-lying areas	Coral reefs	NR	NR	/	/	/	/	/	/	NR	NR	/	/
	Other coastal ecosystems	x	x	/	/	x	x	x	x	NR	NR	x	x
	Arctic coast erosion	/	/	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Food production systems and food security	Rice yield	x	x	/	/	x	/	x	/	x	x	X	/
	Wheat yield	x	x	x	x	x	x	x	/	x	x	/	/
	Corn yield	x	x	x	/	x	x	x	x	x	x	x	x
	Other crops (e.g., barley, potato)	x	x	/	/	x	x	x	x	x	X	/	/
	Vegetables	x	x	/	x	x	x	x	x	x	x	x	x
	Fruits	x	x	/	x	x	x	x	x	x	x	x	x
	Livestock	x	x	/	x	x	x	x	x	x	x	x	x
	Fisheries and aquaculture production	x	/	x	/	x	/	x	x	x	x	x	x
	Farming area	x	/	x	/	x	x	x	/	x	/	x	x
	Water demand for irrigation	x	/	x	/	x	x	x	/	x	x	x	x
Pest and disease occurrence	x	x	x	x	x	x	x	/	x	x	x	x	
Human settlements, industry, and infrastructure	Floodplains	x	x	/	/	/	/	/	/	x	x	x	x
	Coastal areas	x	x	/	/	/	/	/	/	NR	NR	x	x
	Population and assets	x	x	/	/	/	/	/	/	x	x	x	x
	Industry and infrastructure	x	x	/	/	/	/	/	/	x	x	x	x
Human health, security, livelihoods, and poverty	Health effects of floods	x	x	x	x	x	x	/	x	x	x	x	x
	Health effects of heat	x	x	/	x	x	x	x	x	x	x	x	x
	Health effects of drought	x	x	x	x	x	x	x	x	x	x	x	x
	Water-borne diseases	x	x	x	x	/	x	/	x	x	x	x	x
	Vector-borne diseases	x	x	x	x	/	x	/	x	x	x	x	x
	Livelihoods and poverty	x	x	/	x	x	x	/	x	x	x	x	x
Economic valuation	x	x	x	x	/	/	/	/	x	x	x	x	

Key:

/ = Relatively abundant/sufficient information; knowledge gaps need to be addressed but conclusions can be drawn based on existing information.

x = Limited information/no data; critical knowledge gaps, difficult to draw conclusions.

NR = Not relevant.

24.9. Case Studies

24.9.1. Transboundary Adaptation Planning and Management—Lower Mekong River Basin

The Lower Mekong River Basin (LMB) covers an area of approximately 606,000 km² across the countries of Thailand, Laos, Cambodia, and Vietnam. More than 60 million people are heavily reliant on natural resources, in particular agriculture and fisheries, for their well-being (MRC, 2009; UNEP, 2010; Figure SM24-2). Thailand and Vietnam produced 51% of the world's rice exports in 2008, mostly in the LMB (Mainuddin et al., 2011).

Observations of climate change over the past 30 to 50 years in the LMB include an increase in temperature, an increase in rainfall in the wet season and decreases in the dry season, intensified flood and drought events, and sea level rise (ICEM, 2010; IRG, 2010). Agricultural output has been noticeably impacted by intensified floods and droughts which caused almost 90% of rice production losses in Cambodia during 1996–2001 (Brooks and Adger, 2003; MRC, 2009). Vietnam and Cambodia are two of the countries most vulnerable to climate impacts on fisheries (Allison et al., 2009; Halls, 2009).

Existing studies about future climate impacts in the Mekong Basin broadly share a set of common themes (MRC, 2009; Murphy and Sampson, 2013): increased temperature and annual precipitation; increased depth and duration of flood in the Mekong Delta and Cambodia floodplain; prolonged agricultural drought in the south and the east of the basin; and sea level rise and salinity intrusion in the Mekong delta. Hydropower dams along the Mekong River and its tributaries will also have severe impacts on fish productivity and biodiversity, by blocking critical fish migration routes, altering the habitat of non-migratory fish species, and reducing nutrient flows downstream (Costanza et al., 2011; Baran and Guerin, 2012; Ziv et al., 2012). Climate impacts, though less severe than the impact of dams, will exacerbate these changes (Wyatt and Baird, 2007; Grumbine et al., 2012; Orr et al., 2012; Räsänen et al., 2012; Ziv et al., 2012).

National climate change adaptation plans have been formulated in all four LMB countries, but transboundary adaptation planning across the LMB does not exist to date. Effective future transboundary adaptation planning and management will benefit from: a shared climate projection across the LMB for transboundary adaptation planning; improved coordination among adaptation stakeholders and sharing of best practices across countries; mainstreaming climate change adaptation into national and sub-national development plans with proper translation from national adaptation strategies into local action plans; integration of transboundary policy recommendations into national climate change plans and policies; and integration of adaptation strategies on landscape scales between ministries and different levels of government within a country (MRC, 2009; Kranz et al., 2010; Lian and Bhullar, 2011; Lebel et al., 2012).

A study of the state-of-adaptation practice in the LMB showed that only 11% (45 of 417) of climate-change related projects in the LMB were

on-the-ground adaptation efforts driven by climate risks (Ding, 2012; Neo, 2012; Schaffer and Ding, 2012). Common features of “successful” projects include: robust initial gap assessment, engagement of local stakeholders, and a participatory process throughout (Brown, 2012; Khim and Phearnich, 2012; Mondal, 2012; Panyakul, 2012; Roth and Grunbuhel, 2012). A multi-stakeholder Regional Adaptation Action Network has been proposed with the intent of scaling up and improving mainstreaming of adaptation through tangible actions following the theory and successful examples of the Global Action Networks (GANs) (WCD, 2000; Waddell, 2005; Waddell and Khagram, 2007; GAVI, 2012; Schaffer and Ding, 2012).

24.9.2. Glaciers of Central Asia

In the late 20th century, central Asian glaciers occupied 31,628 km² (Dolgushin and Osipova, 1989). All recent basin-scale studies document multi-decadal area loss (see Figure 24-3); where multiple surveys are available, most show accelerating loss. The rate of glacier area change varies (Table SM24-9). Rates between $-0.05\% \text{ yr}^{-1}$ and $-0.76\% \text{ yr}^{-1}$ have been reported in the Altai (Surazakov et al., 2007; Shahgedanova et al., 2010; Yao, X.-J. et al., 2012) and Tien Shan (Lettenmaier et al., 2009; Sorg et al., 2012), and between $-0.13\% \text{ yr}^{-1}$ and $-0.30\% \text{ yr}^{-1}$ in the Pamir (Konovalov and Desinov, 2007; Aizen, 2011a,b,c; Yao, X.-J. et al., 2012). These ranges reflect varying sub-regional distributions of glacier size (smaller glaciers shrink faster) and debris cover (which retards shrinkage), but also varying proportions of ice at high altitudes, where as yet warming has produced little increase in melt (Narama et al., 2010).

Most studies also document mean-annual (e.g., Glazyrin and Tadzhibaeva, 2011, for 1961–1990) and summertime (e.g., Shahgedanova et al., 2010) warming, with slight cooling in the central and eastern Pamir (Aizen, 2011b). Precipitation increases have been observed more often than decreases (e.g., Braun et al., 2009; Glazyrin and Tadzhibaeva, 2011).

Aizen et al. (2007) calculated 21st-century losses of 43% of the volume of Tien Shan glaciers for an 8°C temperature increase accompanied by a 24% precipitation increase, but probable complete disappearance of glaciers if precipitation decreased by 16%; a more moderate 2°C increase led to little loss, but only if accompanied by a 24% precipitation increase. Drawing on CMIP5 simulations, Radić et al. (2013) simulated losses by 2100 of between 25 and 90% of 2006 ice volume (including Tibet Autonomous Region, China, but excluding the Altai and Sayan; range of all single-model simulations); the 14-GCM model mean losses are 55% for RCP4.5 and 75% for RCP8.5. Similarly, Marzeion et al. (2012) found 21st-century volume losses of 50% for RCP2.6, about 57% for both RCP4.5 and RCP6.0, and 67% for RCP8.5.

The glaciers have therefore been a diminishing store of water, and the diminution is projected to continue. Paradoxically, this implies more meltwater, possibly explaining limited observations of increased runoff (Sorg et al., 2012), but also an eventual decrease of meltwater yield (see Section 3.4.4). More immediately, it entails a hazard due to the formation of moraine-dammed glacial lakes (Bolch et al., 2011).

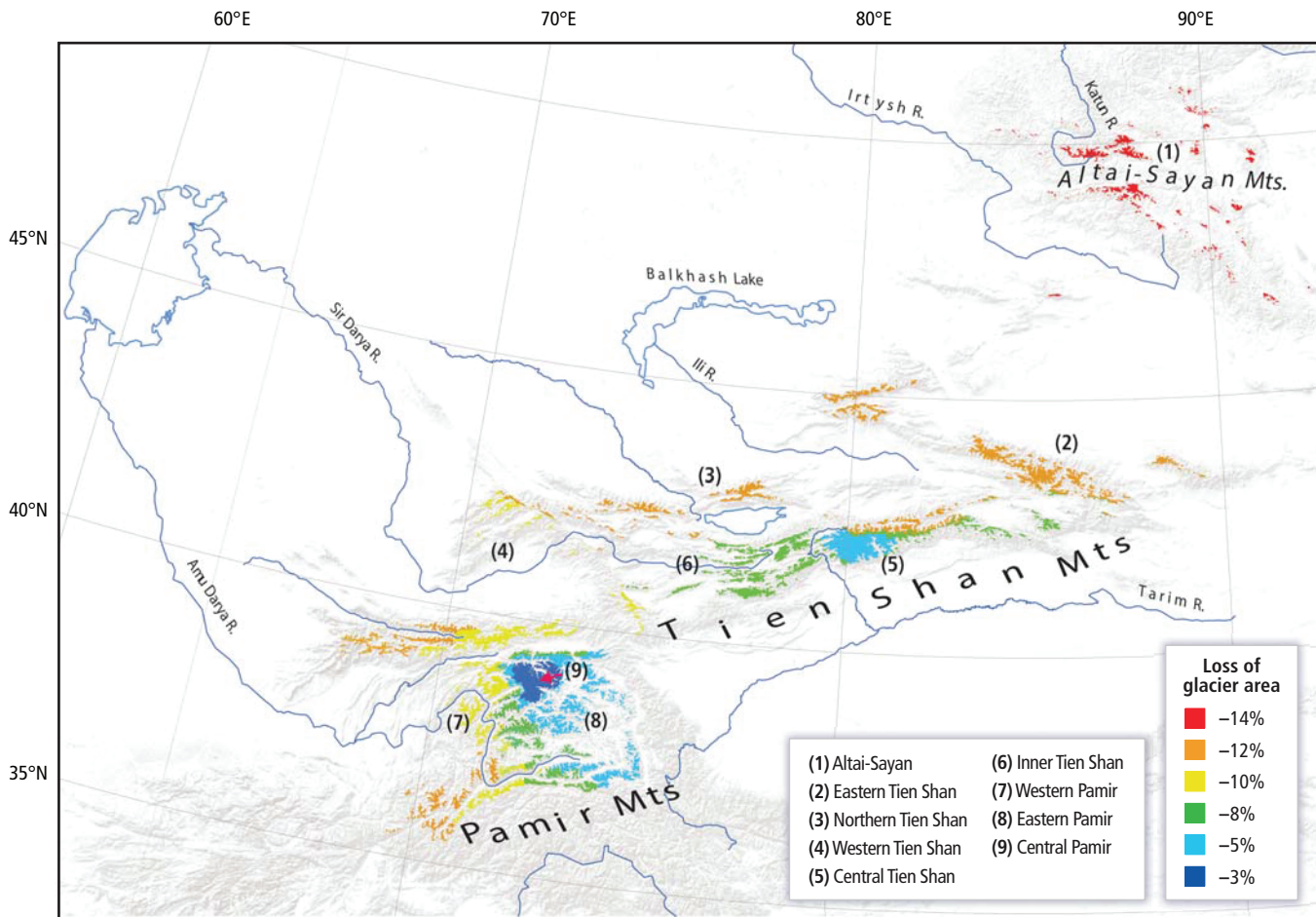


Figure 24-3 | Losses of glacier area in the Altai-Sayan, Pamir, and Tien Shan. Remote-sensing data analysis from 1960s (Corona) through 2008 (Landsat, ASTER, and Alos Prism).

References

- Aarnoudse, E., B. Bluemling, P. Wester, and W. Qu, 2012: The role of collective groundwater institutions in the implementation of direct groundwater regulation measures in Minqin County, China. *Hydrogeology Journal*, **20**(7), 1213-1221.
- Acosta-Michlik, L. and V. Espaldon, 2008: Assessing vulnerability of selected farming communities in the Philippines based on a behavioural model of agent's adaptation to global environmental change. *Global Environmental Change*, **18**(4), 554-563.
- ADB, 2005: *Climate Proofing: A Risk-Based Approach to Adaptation*. Pacific Studies Series, Asian Development Bank (ADB), Manila, Philippines, 191 pp.
- ADB, 2007: *Promoting Climate Change Adaptation in Asia and the Pacific*. Technical Assistance Report, Project No. 39343, Asian Development Bank (ADB), Manila, Philippines, 16 pp.
- ADB, 2009: *The Economics of Climate Change in Southeast Asia: A Regional Review*. Asian Development Bank (ADB), Manila, Philippines, 255 pp.
- ADB, 2012: *Asian Development Outlook 2012: Confronting Rising Inequality in Asia*. Asian Development Bank (ADB), Manila, Philippines, 272 pp.
- Adger, W.N., 2003: Social capital, collective action, and adaptation to climate change. *Economic Geography*, **79**(4), 387-404.
- Agrawal, A. and N. Perrin, 2008: *Climate Adaptation, Local Institutions, and Rural Livelihoods*. IFRI Working Paper W08I-6, International Forestry Resources and Institutions (IFRI) Program, School of Natural Resources and Environment, University of Michigan, Ann Arbor, MI, USA, 17 pp.
- Ahmed, S. and E. Fajber, 2009: Engendering adaptation to climate variability in Gujarat, India. *Gender & Development*, **17**(1), 33-50.
- Aizen, V.B., 2011a: Altai-Sayan glaciers. In: *Encyclopedia of Snow, Ice and Glaciers* [Singh, V.P., P. Singh, and U.K. Haritashya (eds.)]. Springer, Dordrecht, Netherlands, pp. 38-39.
- Aizen, V.B., 2011b: Pamirs. In: *Encyclopedia of Snow, Ice and Glaciers* [Singh, V.P., P. Singh, and U.K. Haritashya (eds.)]. Springer, Dordrecht, Netherlands, pp. 813-815.
- Aizen, V.B., 2011c: Tien Shan glaciers. In: *Encyclopedia of Snow, Ice and Glaciers* [Singh, V.P., P. Singh, and U.K. Haritashya (eds.)]. Springer, Dordrecht, Netherlands, pp. 1179-1181.
- Aizen, V.B., E.M. Aizen, and V.A. Kuzmichonok, 2007: Glaciers and hydrological changes in the Tien Shan: simulation and prediction. *Environmental Research Letters*, **2**(4), 045019, doi:10.1088/1748-9326/2/4/045019.
- Al-Bakri, J., A. Suleiman, F. Abdulla, and J. Ayad, 2010: Potential impact of climate change on rainfed agriculture of a semi-arid basin in Jordan. *Physics and Chemistry of the Earth, Parts A/B/C*, **36**(5-6), 125-134.
- Alauddin, M. and J. Quiggin, 2008: Agricultural intensification, irrigation and the environment in South Asia: issues and policy options. *Ecological Economics*, **65**(1), 111-124.
- Alcarno, J., N. Dronin, M. Endejan, G. Golubev, and A. Kirilenko, 2007: A new assessment of climate change impacts on food production shortfalls and water availability in Russia. *Global Environmental Change*, **17**(3-4), 429-444.
- Alexander, K.S., A. Ryan, and T.G. Measham, 2012: Managed retreat of coastal communities: understanding responses to projected sea level rise. *Journal of Environmental Planning and Management*, **55**(4), 409-433.
- Allen, K.M., 2006: Community-based disaster preparedness and climate adaptation: local capacity-building in the Philippines. *Disasters*, **30**(1), 81-101.
- Allison, E.H., A.L. Perry, M. Badjeck, W.N. Adger, K. Brown, D. Conway, A.S. Hills, G.M. Pilling, J.D. Reynolds, N.L. Andrew, and N.K. Dulvey, 2009: Vulnerability of national economies to the impacts of climate change on fisheries. *Fish and Fisheries*, **10**, 173-196.
- Allison, I., 2011: Papua. In: *Encyclopedia of Snow, Ice and Glaciers* [Singh, V.P., P. Singh, and U.K. Haritashya (eds.)]. Springer, Dordrecht, Netherlands, pp. 815-817.

- Ananicheva, M.D., M.M. Koreisha, and S. Takahashi, 2005: Assessment of glacier shrinkage from the maximum in the Little Ice Age in the Suntar-Khayata Range, North-East Siberia. *Bulletin of Glaciological Research*, **22**, 9-17.
- Ananicheva, M.D., G.A. Kapustin, and M.M. Koreisha, 2006: Glacier changes in the Suntar-Khayata Mountains and Chersky Range from the Glacier Inventory of the USSR and satellite images 2001-2003. *Data of Glaciological Studies*, **101**, 163-168.
- Anderson-Teixeira, K.J., P.K. Snyder, T.E. Twine, S.V. Cuadra, M.H. Costa, and E.H. DeLucia, 2012: Climate-regulation services of natural and agricultural ecoregions of the Americas. *Nature Climate Change*, **2**(3), 177-181.
- Angelsen, A., 2009: *Realizing REDD+: National Strategy and Policy Options*. Center for International Forestry Research (CIFOR), Bogor, Indonesia, 362 pp.
- Anisimov, O.A., Y.A. Anokhin, A.N. Krenke, M.D. Ananicheva, P.M. Lurie, and L.T. Myach, 2008: Continental permafrost and glaciers. In: *Assessment Report on Climate Change and its Consequences in Russian Federation. Volume II: Climate Change Consequences* [Velichko, A.A. (ed.)]. Planeta Publishing, Moscow, Russia, pp. 124-134 (in Russian).
- Anisimov, O.A., 2009: Stochastic modelling of the active layer thickness under conditions of the current and future climate. *Earth's Cryosphere*, **13**(3), 36-44.
- Aragão, L.E.O.C., 2012: The rainforest's water pump. *Nature*, **489**, 217-218.
- Are, F., E. Reimnitz, M. Grigoriev, H.W. Hubberten, and V. Rachold, 2008: The influence of cryogenic processes on the erosional arctic shoreface. *Journal of Coastal Research*, **24**(1), 110-121.
- Arias, M.E., T.A. Cochrane, T. Piman, M. Kumm, B.S. Caruso, and T.J. Killeen, 2012: Quantifying changes in flooding and habitats in the Tonle Sap Lake (Cambodia) caused by water infrastructure development and climate change in the Mekong Basin. *Journal of Environmental Management*, **112**, 53-66.
- Asokan, S.M. and D. Dutta, 2008: Analysis of water resources in the Mahanadi River Basin, India under projected climate conditions. *Hydrological Processes*, **22**(18), 3589-3603.
- Atici, C., 2012: Carbon emissions, trade liberalization, and the Japan-ASEAN interaction: a group-wise examination. *Journal of the Japanese and International Economies*, **26**(1), 167-178.
- Aydinalp, C. and M.S. Cresser, 2008: The effects of global climate change on agriculture. *American-Eurasian Journal of Agriculture & Environmental Sciences*, **3**(5), 672-676.
- Ayers, J.M. and S. Huq, 2009: The value of linking mitigation and adaptation: a case study of Bangladesh. *Environmental Management*, **43**(5), 753-764.
- Baas, S. and S. Ramasamy, 2008: *Community Based Adaptation in Action: a Case Study from Bangladesh*. Food and Agricultural Organization of the United Nations - Headquarters, Rome, Italy, 64 pp.
- Bagchi, S., 2007: Disease outbreaks in wake of Southeast Asia floods. *Canadian Medical Association Journal*, **177**(6), 560-560.
- Bai, F., W. Sang, and J.C. Axmacher, 2011: Forest vegetation responses to climate and environmental change: a case study from Changbai Mountain, NE China. *Forest Ecology and Management*, **262**(11), 2052-2060.
- Banu, S., W. Hu, C. Hurst, and S. Tong, 2011: Dengue transmission in the Asia-Pacific region: impact of climate change and socio-environmental factors. *Tropical Medicine & International Health*, **16**(5), 598-607.
- Baran, E. and E. Guerin, 2012: *Dams, Changes in Sediment Load and Impact on Fish Resources in the Mekong: Approach and Way Forward*. Report for the Project "A Climate Resilient Mekong: Maintaining the Flows that Nourish Life" led by the Natural Heritage Institute, WorldFish Center, Phnom Penh, Cambodia, 19 pp.
- Barange, M. and R.I. Perry, 2009: Physical and ecological impacts of climate change relevant to marine and inland capture fisheries and aquaculture. In: *Climate Change Implications for Fisheries and Aquaculture. Overview of Current Scientific Knowledge* [Cochrane, K., C. De Young, D. Soto, and T. Bahri (eds.)]. FAO Fisheries and Aquaculture Technical Paper 530, Food and Agriculture Organization of the United Nations (FAO), Rome, Italy, pp. 7-106.
- Barker, R. and G. Levine, 2012: *Water Productivity in Context: The Experiences of Taiwan and the Philippines over the Past Half-Century*. IWMI Research Report 145, International Water Management Institute (IWMI), Colombo, Sri Lanka, 25 pp.
- Barnett, J.R. and M. Webber, 2010: *Accommodating Migration to Promote Adaptation to Climate Change*. Policy Research Working Paper 5270, Background paper to the 2010 World Development Report, The World Bank, Washington, DC, USA, 61 pp.
- Barrett, C.B., B.J. Barnett, M.R. Carter, S. Chantarat, J.W. Hansen, A.G. Mude, D.E. Osgood, J.R. Skees, C.G. Turvey, and M.N. Ward, 2007: *Poverty Traps and Climate and Weather Risk: Limitations and Opportunities of Index-Based Risk Financing*. IRI Technical Report 07-03, International Research Institute for Climate and Society (IRI), Earth Institute, Columbia University Lamont Campus, Palisades, NY, USA, 54 pp.
- Bates, B.C., Z.W. Kundzewicz, S. Wu, and J.P. Palutikof (eds.), 2008: *Climate Change and Water*. Technical Paper of the Intergovernmental Panel on Climate Change (IPCC). IPCC Secretariat, Geneva, Switzerland, 200 pp.
- Battarbee, R.W., N.J. Anderson, H. Bennion, and G.L. Simpson, 2012: Combining limnological and palaeolimnological data to disentangle the effects of nutrient pollution and climate change on lake ecosystems: problems and potential. *Freshwater Biology*, **57**(10), 2091-2106.
- Beaumont, L.J., A. Pitman, S. Perkins, N.E. Zimmermann, N.G. Yoccoz, and W. Thuiller, 2010: Impacts of climate change on the world's most exceptional ecoregions. *Proceedings of the National Academy of Sciences of the United States of America*, **108**(6), 2306-2311.
- Béguin, A., S. Hales, J. Rocklöv, C. Åström, V.R. Louis, and R. Sauerborn, 2011: The opposing effects of climate change and socio-economic development on the global distribution of malaria. *Global Environmental Change*, **21**(4), 1209-1214.
- Begum, R.A., R.D.Z.R.Z. Abidin, and J.J. Pereira, 2011: Initiatives and market mechanisms for climate change actions in Malaysia. *Journal of Environmental Science and Technology*, **4**(1), 31-40.
- Bezuijen, M.R., 2011: *Wetland Biodiversity & Climate Change Briefing Paper: Rapid Assessment of the Impacts of Climate Change to Wetland Biodiversity in the Lower Mekong Basin*. Basin-Wide Climate Change Impact and Vulnerability Assessment for Wetlands of The Lower Mekong Basin for Adaptation Planning, RFP No. 10-240, Prepared for the Mekong River Commission (MRC) by the International Centre for Environmental Management (ICEM), Hanoi, Vietnam, 37 pp.
- Bharati, L., G. Lacombe, P. Gurung, P. Jayakody, C.T. Hoanh, and V. Smakhtin, 2011: *The Impacts of Water Infrastructure and Climate Change on the Hydrology of the Upper Ganges River Basin*. IWMI Research Report 142, International Water Management Institute (IWMI), Colombo, Sri Lanka, 36 pp.
- Bhattachan, A., S. Amatyia, T.R. Sedai, S.R. Upreti, and J. Partridge, 2009: Japanese encephalitis in hill and mountain districts, Nepal. *Emerging Infectious Diseases*, **15**(10), 1691-1692.
- Bi, J., L. Xu, A. Samanta, Z. Zhu, and R. Myneni, 2013: Divergent Arctic-Boreal vegetation changes between North America and Eurasia over the past 30 years. *Remote Sensing*, **5**(5), 2093-2112.
- Bi, P., Y. Zhang, and K.A. Parton, 2007: Weather variables and Japanese encephalitis in the metropolitan area of Jinan city, China. *Journal of Infection*, **55**(6), 551-556.
- Bickford, D., S.D. Howard, D.J.J. Ng, and J.A. Sheridan, 2010: Impacts of climate change on the amphibians and reptiles of Southeast Asia. *Biodiversity and Conservation*, **19**(4), 1043-1062.
- Biemans, H., I. Haddeland, P. Kabat, F. Ludwig, R.W.A. Hutjes, J. Heinke, W. von Bloh, and D. Gerten, 2011: Impact of reservoirs on river discharge and irrigation water supply during the 20th century. *Water Resources Research*, **47**, W03509, doi:10.1029/2009WR008929.
- Birkmann, J., M. Garschagen, F. Kraas, and N. Quang, 2010: Adaptive urban governance: new challenges for the second generation of urban adaptation strategies to climate change. *Sustainability Science*, **5**(2), 185-206.
- Biswas, A.K. and K.E. Seetharam, 2008: Achieving water security for Asia. *International Journal of Water Resources Development*, **24**(1), 145-176.
- Blanchard, J.L., S. Jennings, R. Holmes, J. Harle, G. Merino, J.I. Allen, J. Holt, N.K. Dulvy, and M. Barange, 2012: Potential consequences of climate change for primary production and fish production in large marine ecosystems. *Philosophical Transactions of the Royal Society B*, **367**(1605), 2979-2989.
- Blok, D., U. Sass-Klaassen, G. Schaepman-Strub, M.M.P.D. Heijmans, P. Sauren, and F. Berendse, 2011: What are the main climate drivers for shrub growth in Northeastern Siberian tundra? *Biogeosciences*, **8**(5), 1169-1179.
- Bogner, J., R. Pipatti, S. Hashimoto, C. Diaz, K. Mareckova, L. Diaz, P. Kjeldsen, S. Monni, A. Faaij, G. Qingxian, Z. Tianzhu, A. Mohammed Abdelrafie, R.T.M. Sutarnihardja, and R. Gregory, 2008: Mitigation of global greenhouse gas emissions from waste: conclusions and strategies from the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report. Working Group III (Mitigation). *Waste Management & Research*, **26**(1), 11-32.
- Bolch, T., J. Peters, A. Yegorov, B. Pradhan, M. Buchroithner, and V. Blagoveshchensky, 2011: Identification of potentially dangerous glacial lakes in the northern Tien Shan. *Natural Hazards*, **59**(3), 1691-1714.

- Bolton, J.J.**, 2010: The biogeography of kelps (Laminariales, Phaeophyceae): a global analysis with new insights from recent advances in molecular phylogenetics. *Helgolander Marine Research*, **64(4)**, 263-279.
- Borgaonkar, H.P., A.B. Sikder, and S. Ram**, 2011: High altitude forest sensitivity to the recent warming: a tree-ring analysis of conifers from Western Himalaya, India. *Quaternary International*, **236(1-2)**, 158-166.
- Branch, T.A., B.M. DeJoseph, L.J. Ray, and C.A. Wagner**, 2013: Impacts of ocean acidification on marine seafood. *Trends in Ecology and Evolution*, **28(3)**, 178-186.
- Braun, L.N., W. Hagg, I.V. Severskiy, and G. Young (eds.)**, 2009: *Assessment of Snow, Glacier and Water Resources in Asia: Selected Papers from the Workshop in Almaty, Kazakhstan, 2006*. IHP/HWRP Report No. 8, the German National Committee for the United Nations Educational, Scientific and Cultural Organization, International Hydrological Programme (UNESCO IHP) and the World Meteorological Organization, Hydrology and Water Resources Programme (WMO HWRP), IHP/HWRP Secretariat, Koblenz, Germany, 183 pp.
- Brooks, N. and W.N. Adger**, 2003: *Country Level Risk Measures of Climate-related Natural Disasters and Implications for Adaptation to Climate Change*. Tyndall Centre Working Paper No. 26, Tyndall Centre for Climate Change Research, School of Environmental Sciences, University of East Anglia, Norwich, UK, 25 pp.
- Brouwer, R., S. Akter, L. Brander, and E. Haque**, 2007: Socioeconomic vulnerability and adaptation to environmental risk: a case study of climate change and flooding in Bangladesh. *Risk Analysis*, **27(2)**, 313-326.
- Brown, B.E., R.P. Dunne, N. Phongsuwan, and P.J. Somerfield**, 2011: Increased sea level promotes coral cover on shallow reef flats in the Andaman Sea, eastern Indian Ocean. *Coral Reefs*, **30(4)**, 867-878.
- Brown, S.M.**, 2012: The conservation and development of the Kien Giang Biosphere Reserve: adaptation to climate change. **4(4)**, 505-526.
- Brutsaert, W. and M. Sugita**, 2008: Is Mongolia's groundwater increasing or decreasing? The case of the Kherlen River basin. *Hydrological Sciences Journal*, **53(6)**, 1221-1229.
- Burke, L., K. Reytar, M. Spalding, and A. Perry**, 2011: *Reefs at Risk Revisited*. World Resources Institute (WRI), Washington, DC, USA, 114 pp.
- Busch, J., R.N. Lubowski, F. Godoy, M. Steininger, A.A. Yusuf, K. Austin, J. Hewson, D. Juhn, M. Farid, and F. Boltz**, 2012: Structuring economic incentives to reduce emissions from deforestation within Indonesia. *Proceedings of the National Academy of Sciences of the United States of America*, **109(4)**, 1062-1067.
- Byg, A. and J. Salick**, 2009: Local perspectives on a global phenomenon – climate change in eastern Tibetan villages. *Global Environmental Change*, **19(2)**, 156-166.
- Cai, W., C. Wang, J. Chen, K. Wang, Y. Zhang, and X. Lu**, 2008: Comparison of CO₂ emission scenarios and mitigation opportunities in China's five sectors in 2020. *Energy Policy*, **36(3)**, 1181-1194.
- Cai, X., B.R. Sharma, M.A. Matin, D. Sharma, and S. Gunasinghe**, 2010: *An Assessment of Crop Water Productivity in the Indus and Ganges River Basins: Current Status and Scope for Improvement*. IWMI Research Report 140, International Water Management Institute (IWMI), Colombo, Sri Lanka, 22 pp.
- Campbell, B.M.**, 2009: Beyond Copenhagen: REDD+, agriculture, adaptation strategies and poverty. *Global Environmental Change*, **19(4)**, 397-399.
- Casassa, G., P. Lopéz, B. Pouyaud, and F. Escobar**, 2009: Detection of changes in glacial run-off in alpine basins: examples from North America, the Alps, central Asia and the Andes. *Hydrological Processes*, **23(1)**, 31-41.
- Champhong, A., D. Komori, M. Kiguchi, T. Sukhappunnaphan, T. Oki, and T. Nakaegawa**, 2013: Future projection of mean river discharge climatology for the Chao Phraya River basin. *Hydrological Research Letters*, **7(2)**, 36-41.
- Chaturvedi, R.K., R. Gopalakrishnan, M. Jayaraman, G. Bala, N.V. Joshi, R. Sukumar, and N.H. Ravindranath**, 2011: Impact of climate change on Indian forests: a dynamic vegetation modeling approach. *Mitigation and Adaptation Strategies for Global Change*, **16(2)**, 119-142.
- Chen, F., Y.-j. Yuan, W.-s. Wei, Z.-a. Fan, T.-w. Zhang, H.-m. Shang, R.-b. Zhang, S.-l. Yu, C.-r. Ji, and L. Qin**, 2012a: Climatic response of ring width and maximum latewood density of *Larix sibirica* in the Altay Mountains, reveals recent warming trends. *Annals of Forest Science*, **69(6)**, 723-733.
- Chen, F., Y.-j. Yuan, W.-s. Wei, S.-l. Yu, Z.-a. Fan, R.-b. Zhang, T.-w. Zhang, Q. Li, and H.-m. Shang**, 2012b: Temperature reconstruction from tree-ring maximum latewood density of Qinghai spruce in middle Hexi Corridor, China. *Theoretical and Applied Climatology*, **107(3-4)**, 633-643.
- Chen, F., Y.-j. Yuan, W.-s. Wei, S.-l. Yu, and T.-w. Zhang**, 2012c: Tree ring-based winter temperature reconstruction for Changting, Fujian, subtropical region of Southeast China, since 1850: linkages to the Pacific Ocean. *Theoretical and Applied Climatology*, **109(1-2)**, 141-151.
- Chen, F., Y.-j. Yuan, W.-s. Wei, S.-l. Yu, and T.-w. Zhang**, 2012d: Reconstructed temperature for Yong'an, Fujian, Southeast China: linkages to the Pacific Ocean climate variability. *Global and Planetary Change*, **86-87**, 11-19.
- Chen, I.C., J.K. Hill, H.J. Shiu, J.D. Holloway, S. Benedick, V.K. Chey, H.S. Barlow, and C.D. Thomas**, 2011: Asymmetric boundary shifts of tropical montane Lepidoptera over four decades of climate warming. *Global Ecology and Biogeography*, **20(1)**, 34-45.
- Chen, J., C.H. Cannon, and H. Hu**, 2009: Tropical botanical gardens: at the *in situ* ecosystem management frontier. *Trends in Plant Science*, **14(11)**, 584-589.
- Chen, Z., X. Zhang, X. He, N.K. Davi, M. Cui, J. Peng**, 2013: Extension of summer (June-August) temperature records for northern Inner Mongolia (1715-2008), China using tree rings. *Quaternary International*, **283**, 21-29.
- Cheng, G.D. and T.H. Wu**, 2007: Responses of permafrost to climate change and their environmental significance, Qinghai-Tibet Plateau. *Journal of Geophysical Research: Earth Surface*, **112(F2)**, F02S03, doi:10.1029/2006JF000631.
- Cheung, W.W.L., V.W.Y. Lam, J.L. Sarmiento, K. Kearney, R. Watson, and D. Pauly**, 2009: Projecting global marine biodiversity impacts under climate change scenarios. *Fish and Fisheries*, **10(3)**, 235-251.
- Cheung, W.W.L., V.W.Y. Lam, J.L. Sarmiento, K. Kearney, R. Watson, D. Zeller, and D. Pauly**, 2010: Large-scale redistribution of maximum fisheries catch potential in the global ocean under climate change. *Global Change Biology*, **16(1)**, 24-35.
- Cheung, W.W.L., J.L. Sarmiento, J. Dunne, T.L. Frölicher, V.W.Y. Lam, M.L.D. Palomares, R. Watson, and D. Pauly**, 2013: Shrinking of fishes exacerbates impacts of global ocean changes on marine ecosystems. *Nature Climate Change*, **3(3)**, 254-258.
- Chhatre, A. and A. Agrawal**, 2009: Trade-offs and synergies between carbon storage and livelihood benefits from forest communities. *Proceedings of the National Academy of Sciences of the United States of America*, **106(42)**, 17667-17670.
- Chhokar, K.B.**, 2010: Higher education and curriculum innovation for sustainable development in India. *International Journal of Sustainability in Higher Education*, **11(2)**, 141-152.
- Choi, S., W.K. Lee, D.A. Kwak, S. Lee, Y. Son, J.H. Lim, and J. Saborowski**, 2011: Predicting forest cover changes in future climate using hydrological and thermal indices in South Korea. *Climate Research*, **49(3)**, 229-245.
- Chou, C., T. Huang, Y. Lee, C. Chen, T. Hsu, and C. Chen**, 2011: Diversity of the alpine vegetation in central Taiwan is affected by climate change based on a century of floristic inventories. *Botanical Studies*, **52(4)**, 503-516.
- Chou, W.-C., J.-L. Wu, Y.-C. Wang, H. Huang, F.-C. Sung, and C.-Y. Chuang**, 2010: Modeling the impact of climate variability on diarrhea-associated diseases in Taiwan (1996-2007). *Science of the Total Environment*, **409(1)**, 43-51.
- Christensen, J.H., B. Hewitson, A. Busiuc, A. Chen, X. Gao, I. Held, R. Jones, R.K. Kolli, W.-T. Kwon, R. Laprise, V.M. Rueda, L. Mearns, C.G. Menéndez, J. Räisänen, A. Rinke, A. Sarr, and P. Whetton**, 2007: Regional climate projections. In: *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor, and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 847-940.
- Chung, J.-Y., Y. Honda, Y.-C. Hong, X.-C. Pan, Y.-L. Guo, and H. Kim**, 2009: Ambient temperature and mortality: an international study in four capital cities of East Asia. *Science of the Total Environment*, **408(2)**, 390-396.
- CIA**, 2013: *The World Factbook: Country Comparison: Life Expectancy at Birth*. United States Central Intelligence Agency (CIA), Washington, DC, USA, <https://www.cia.gov/library/publications/the-world-factbook/rankorder/2102rank.html>.
- Clough, Y., J. Barkmann, J. Jührbandt, M. Kessler, T.C. Wanger, A. Anshary, D. Buchori, D. Cicuzza, K. Darras, D.D. Putra, S. Erasmí, R. Pitopang, C. Schmidt, C.H. Schulze, D. Seidel, I. Steffan-Dewenter, K. Stenchly, S. Vidal, M. Weist, A.C. Wielgoss, and T. Tschardt**, 2011: Combining high biodiversity with high yields in tropical agroforests. *Proceedings of the National Academy of Sciences of the United States of America*, **108(20)**, 8311-8316.
- Cook, E.R., P.J. Krusic, K.J. Anchukaitis, B.M. Buckley, T. Nakatsuka, and M. Sano**, 2012: Tree-ring reconstructed summer temperature anomalies for temperate East Asia since 800 C.E. *Climate Dynamics*, **41(11-12)**, 2957-2972.
- Corlett, R.T.**, 2011: Impacts of warming on tropical lowland rainforests. *Trends in Ecology and Evolution*, **26(11)**, 606-613.
- Corlett, R.T. and D.A. Westcott**, 2013: Will plant movements keep up with climate change? *Trends in Ecology and Evolution*, **28(8)**, 482-488.

- Costanza, R.**, I. Kybiszewski, P. Paquet, J. King, S. Halimi, H. Sanguanngoi, N.L. Bach, R. Frankel, J. Ganaseeni, A. Intralawan, and D. Morrell, 2011: *Planning Approaches for Water Resources Development in the Lower Mekong Basin*. Portland State University, Portland, OR, USA and Mae Fah Luang University, Chiang Rai, Thailand, 83 pp.
- Coulthard, S.**, 2008: Adapting to environmental change in artisanal fisheries – insights from a South Indian Lagoon. *Global Environmental Change*, **18**(3), 479-489.
- Cristea, A.**, D. Hummels, L. Puzello, and M. Avetisyan, 2013: Trade and the greenhouse gas emissions from international freight transport. *Journal of Environmental Economics and Management*, **65**(1), 153-173.
- Crooks, S.**, D. Herr, J. Tamelander, D. Laffoley, and J. Vandever, 2011: *Mitigating Climate Change Through Restoration and Management of Coastal Wetlands and Near-Shore Marine Ecosystems: Challenges and Opportunities*. Environment Department Papers No. 121, The World Bank, Washington, DC, USA, 59 pp.
- Dahal, S.**, 2008: Climatic determinants of malaria and kala-azar in Nepal. *Regional Health Forum*, **12**(1), 32-37.
- Daniau, A.L.**, P.J. Bartlein, S.P. Harrison, I.C. Prentice, S. Brewer, P. Friedlingstein, T.I. Harrison-Prentice, J. Inoue, K. Izumi, J.R. Marlon, S. Mooney, M.J. Power, J. Stevenson, W. Tinner, M. Andric, J. Atanassova, H. Behling, M. Black, O. Blarquez, K.J. Brown, C. Carcaillet, E.A. Colhoun, D. Colombaroli, B.A.S. Davis, D. D'Costa, J. Dodson, L. Dupont, Z. Eshetu, D.G. Gavin, A. Genries, S. Haberle, D.J. Hallett, G. Hope, S.P. Horn, T.G. Kassa, F. Katamura, L.M. Kennedy, P. Kershaw, S. Krivonogov, C. Long, D. Magri, E. Marinova, G.M. McKenzie, P.I. Moreno, P. Moss, F.H. Neumann, E. Norström, C. Pairet, R. Rius, N. Roberts, G.S. Robinson, N. Sasaki, L. Scott, H. Takahara, V. Terwilliger, F. Thevenon, R. Turner, V.G. Valsecchi, B. Vannièrè, M. Walsh, N. Williams, and Y. Zhang, 2012: Predictability of biomass burning in response to climate changes. *Global Biogeochemical Cycles*, **26**(4), GB4007, doi:10.1029/2011GB004249.
- Dasgupta, S.**, B. Laplante, C. Meisner, D. Wheeler, and J. Yan, 2009: The impact of sea level rise on developing countries: a comparative analysis. *Climatic Change*, **93**(3-4), 379-388.
- Davi, N.K.**, G.C. Jacoby, R.D. D'Arrigo, N. Baatarbileg, J. Li, and A.E. Curtis, 2009: A tree-ring-based drought index reconstruction for far-western Mongolia: 1565-2004. *International Journal of Climatology*, **29**(10), 1508-1514.
- Davydov, E.A.**, G.E. Insarov, and A.K. Sundetpaev, 2013: Lichen monitoring in Katon-Karagai National Park, Eastern Kazakhstan in context of climate change. *Programs of Ecological Monitoring and Ecosystem Modelling*, **25**, 11 pp.
- Dawe, D.**, P. Moya, and S. Valencia, 2008: Institutional, policy and farmer responses to drought: El Niño events and rice in the Philippines. *Disasters*, **33**(2), 291-307.
- de Jong, R.**, J. Verbesselt, M.E. Schaepman, and S. de Bruin, 2012: Trend changes in global greening and browning: contribution of short-term trends to longer-term change. *Global Change Biology*, **18**(2), 642-655.
- De Silva, S.S.** and D. Soto, 2009: Climate change and aquaculture: potential impacts, adaptation and mitigation. In: *Climate Change Implications for Fisheries and Aquaculture. Overview of Current Scientific Knowledge* [Cochrane, K., C.D. Young, D. Soto, and T. Bahri (eds.)]. FAO Fisheries and Aquaculture Technical Paper No. 530, Food and Agriculture Organization of the United Nations (FAO), Rome, Italy, pp. 151-212.
- Delbart, N.**, G. Picard, T. Le Toan, L. Kergoat, S. Quegan, I.A.N. Woodward, D. Dye, and V. Fedotova, 2008: Spring phenology in boreal Eurasia over a nearly century time scale. *Global Change Biology*, **14**(3), 603-614.
- Dellink, R.**, M. den Elzen, H. Aiking, E. Bergsma, F. Berkhout, T. Dekker, and J. Gupta, 2009: Sharing the burden of financing adaptation to climate change. *Global Environmental Change* **19**(4), 411-421.
- Delpla, I.**, A.V. Jung, E. Baures, M. Clement, and O. Thomas, 2009: Impacts of climate change on surface water quality in relation to drinking water production. *Environment International*, **35**(8), 1225-1233.
- Dev, S.M.**, 2011: *Climate Change, Rural Livelihoods and Agriculture (Focus on Food Security) in Asia-Pacific Region*. WP-2011-014, Indira Gandhi Institute of Development Research, Mumbai, India, 65 pp.
- Dev, V.** and A. Dash, 2007: Rainfall and malaria transmission in north-eastern India. *Annals of Tropical Medicine and Parasitology*, **101**(5), 457-459.
- Devi, N.P.** and R. Jauhari, 2006: Climatic variables and malaria incidence in Dehradun, Uttaranchal, India. *Journal of Vector Borne Diseases*, **43**(1), 21-28.
- Diaz, S.**, A. Hector, and D.A. Wardle, 2009: Biodiversity in forest carbon sequestration initiatives: not just a side benefit. *Current Opinion in Environmental Sustainability*, **1**(1), 55-60.
- Ding, L.**, 2012: Application of an operational framework for identifying successful adaptation projects in the Lower Mekong Basin. *Asian Journal of Environment and Disaster Risk Management (AJEDM)*, **4**(4), 379-395.
- Dolgushin, L.D.** and G.B. Osipova, 1989: *Ledniki [Glaciers]*. Mysl' Publishers, Moscow, Russian Federation, 447 pp.
- Donato, D.C.**, J.B. Kauffman, D. Murdiyarto, S. Kurnianto, M. Stidham, and M. Kanninen, 2011: Mangroves among the most carbon-rich forests in the tropics. *Nature Geoscience*, **4**(5), 293-297.
- Doney, S.C.**, M. Ruckelshaus, J.E. Duffy, J.P. Barry, F. Chan, C.A. English, H.M. Galindo, J.M. Grebmeier, A.B. Hollowed, N. Knowlton, J. Polovina, N.N. Rabalais, W.J. Sydeman, and L.D. Talley, 2012: Climate change impacts on marine ecosystems. *Annual Review of Marine Science*, **4**, 11-37.
- Dong, J.**, G. Zhang, Y. Zhang, and X. Xiao, 2013: Reply to Wang et al.: snow cover and air temperature affect the rate of changes in spring phenology in the Tibetan Plateau. *Proceedings of the National Academy of Sciences of the United States of America*, **110**(31), E2856-E2857.
- Donohue, R.J.**, M.L. Roderick, T.R. McVicar, and G.D. Farquhar, 2013: Impact of CO₂ fertilization on maximum foliage cover across the globe's warm, arid environments. *Geophysical Research Letters*, **40**(12), 3031-3035.
- Dorigo, W.**, R. de Jeu, D. Chung, R. Parinussa, Y. Liu, W. Wagner, and D. Fernández-Prieto, 2012: Evaluating global trends (1988-2010) in harmonized multi-satellite surface soil moisture. *Geophysical Research Letters*, **39**(18), L18405, doi:10.1029/2012GL052988.
- Douglas, I.**, 2009: Climate change, flooding and food security in south Asia. *Food Security*, **1**(2), 127-136.
- Duan, J.**, L. Wang, L. Li, and K. Chen, 2010: Temperature variability since A.D. 1837 inferred from tree-ring maximum density of *Abies fabri* on Gongga Mountain, China. *Chinese Science Bulletin*, **55**(26), 3015-3022.
- Dudgeon, D.**, 2011: Asian river fishes in the Anthropocene: threats and conservation challenges in an era of rapid environmental change. *Journal of Fish Biology*, **79**(6 SI), 1487-1524.
- Dudgeon, D.**, 2012: Threats to freshwater biodiversity globally and in the Indo-Burma Biodiversity Hotspot. In: *The Status and Distribution of Freshwater Biodiversity in Indo-Burma* [Allen, D.J., K.G. Smith, and W.R.T. Darwall (eds.)]. International Union for Conservation of Nature (IUCN), Cambridge, UK, pp. 1-28.
- Dulamsuren, C.**, M. Hauck, and C. Leuschner, 2010a: Recent drought stress leads to growth reductions in *Larix sibirica* in the western Khentey, Mongolia. *Global Change Biology*, **16**(11), 3024-3035.
- Dulamsuren, C.**, M. Hauck, M. Khishigjargal, H.H. Leuschner, and C. Leuschner, 2010b: Diverging climate trends in Mongolian taiga forests influence growth and regeneration of *Larix sibirica*. *Oecologia*, **163**(4), 1091-1102.
- Dulamsuren, C.**, M. Hauck, H. Leuschner, and C. Leuschner, 2011: Climate response of tree-ring width in *Larix sibirica* growing in the drought-stressed forest-steppe ecotone of northern Mongolia. *Annals of Forest Science*, **68**(2), 275-282.
- Dun, O.**, 2011: Migration and displacement triggered by floods in the Mekong Delta. *International Migration*, **49**(1), e200-e223.
- Dutrieux, L.P.**, H. Bartholomeus, M. Herold, and J. Verbesselt, 2012: Relationships between declining summer sea ice, increasing temperatures and changing vegetation in the Siberian Arctic tundra from MODIS time series (2000-11). *Environmental Research Letters*, **7**(4), 044028, doi:10.1088/1748-9326/7/4/044028.
- ECA**, 2009: *Shaping Climate-Resilient Development: A Framework for Decision-Making*. Report of the Economics of Climate Adaptation (ECA) Working Group, a partnership of Climate Works Foundation, Global Environment Facility, European Commission, McKinsey & Company, The Rockefeller Foundation, Standard Chartered Bank, and Swiss Re, 159 pp., ec.europa.eu/development/icenter/repository/ECA_Shaping_Climate_Resilient_Development.pdf.
- Eichler, A.**, W. Tinner, S. Brüttsch, S. Olivier, T. Papina, and M. Schwikowski, 2011: An ice-core based history of Siberian forest fires since AD 1250. *Quaternary Science Reviews*, **30**(9-10), 1027-1034.
- Eliseev, A.V.**, M.M. Arzhanov, P.F. Demchenko, and Mokhov, II, 2009: Changes in climatic characteristics of Northern Hemisphere extratropical land in the 21st century: assessments with the IAP RAS climate model. *Izvestiya Atmospheric and Oceanic Physics*, **45**(3), 271-283.
- Ensor, J.** and R. Berger, 2009: *Understanding Climate Change Adaptation: Lessons from Community-Based Approaches*. Practical Action, Bourton-on-Dunsmore, UK, 208 pp.
- Epstein, H.E.**, M.K. Reynolds, D.A. Walker, U.S. Bhatt, C.J. Tucker, and J.E. Pinzon, 2012: Dynamics of aboveground phytomass of the circumpolar Arctic tundra during the past decades. *Environmental Research Letters*, **7**(1), 015506.

- Estudillo, J.P.** and K. Otsuka, 2010: Rural poverty and income dynamics in Southeast Asia. *Handbook of Agricultural Economics*, **4**, 3434-3468.
- Evans, A.**, 2010: *Resource Scarcity, Climate Change and the Risk of Violent Conflict*. Background Paper, World Development Report 2011, The World Bank, Washington, DC, USA, 23 pp.
- FAO**, 2010: *The State of the World Fisheries and Agriculture 2010*. Food and Agriculture Organization of the United Nations (FAO), Fisheries and Aquaculture Department, Rome, Italy, 197 pp.
- FAOSTAT**, 2011: *Faostat Popstat*. Statistics Division of the Food and Agriculture Organization of the United Nations (FAOSTAT), faostat3.fao.org/faostat-gateway/go/to/home/E.
- Fargione, J.E.**, R.J. Plevin, and J.D. Hill, 2010: The ecological impact of biofuels. *Annual Review of Ecology, Evolution, and Systematics*, **41**, 351-377.
- Flannigan, M.D.**, M.A. Krawchuk, W.J. de Groot, B.M. Wotton, and L.M. Gowman, 2009: Implications of changing climate for global wildland fire. *International Journal of Wildland Fire*, **18(5)**, 483-507.
- Fleischer, A.**, R. Mendelsohn, and A. Dinar, 2011: Bundling agricultural technologies to adapt to climate change. *Technological Forecasting and Social Change*, **78(6)**, 982-990.
- Forrest, J.L.**, E. Wikramanayake, R. Shrestha, G. Arendran, K. Gyeltshen, A. Maheshwari, S. Mazumdar, R. Naidoo, G.J. Thapa, and K. Thapa, 2012: Conservation and climate change: assessing the vulnerability of snow leopard habitat to treeline shift in the Himalaya. *Biological Conservation*, **150(1)**, 129-135.
- Fuchs, R.**, M. Conran, and E. Louis, 2011: Climate change and Asia's coastal urban cities: can they meet the challenge? *Environment and Urbanization Asia*, **2(1)**, 13-28.
- Fung, F.**, A. Lopez, and M. New, 2011: Water availability in +2 degrees C and +4 degrees C worlds. *Philosophical Transactions of the Royal Society A*, **369(1934)**, 99-116.
- Gaillard, J.-C.**, C.C. Liamzon, and J.D. Villanueva, 2007: 'Natural' disaster? A retrospect into the causes of the late-2004 typhoon disaster in Eastern Luzon, Philippines. *Environmental Hazards*, **7(4)**, 257-270.
- Game, E.T.**, G. Lipsett-Moore, E. Saxon, N. Peterson, and S. Sheppard, 2011: Incorporating climate change adaptation into national conservation assessments. *Global Change Biology*, **17(10)**, 3150-3160.
- García-López, J.M.** and C. Allué, 2013: Modelling future no-analogue climate distributions: a world-wide phytoclimatic niche-based survey. *Global and Planetary Change*, **101**, 1-11.
- Gardner, A.S.**, G. Moholdt, J.G. Cogley, B. Wouters, A.A. Arendt, J. Wahr, E. Berthier, R. Hock, W.T. Pfeffer, G. Kaser, S.R.M. Ligtenberg, T. Bolch, M.J. Sharp, J.O. Hagen, M.R. van den Broeke, and F. Paul, 2013: A reconciled estimate of glacier contributions to sea level rise: 2003 to 2009. *Science*, **340(6134)**, 852-857.
- Garg, A.**, R. Dhiman, S. Bhattacharya, and P. Shukla, 2009: Development, malaria and adaptation to climate change: a case study from India. *Environmental Management*, **43(5)**, 779-789.
- Garschagen, M.** and F. Kraas, 2011: Urban climate change adaptation in the context of transformation: lessons from Vietnam. In: *Resilient Cities: Cities and Adaptation to Climate Change – Proceedings of the Global Forum 2010* [Otto-Zimmermann, K. (ed.)]. Springer, Dordrecht, Netherlands, pp. 131-139.
- Garschagen, M.**, F.G. Renaud, and J. Birkmann, 2011: Dynamic resilience of peri-urban agriculturalists in the Mekong Delta under pressures of socio-economic transformation and climate change. In: *Environmental Change and Agricultural Sustainability in the Mekong Delta* [Stewart, M.A. and P.A. Cooclanis (eds.)]. Springer, Dordrecht, Netherlands, pp. 141-163.
- Gautam, P.K.**, 2012: Climate change and conflict in South Asia. *Strategic Analysis*, **36(1)**, 32-40.
- Gautam, R.**, N.C. Hsu, T.F. Eck, B.N. Holben, S. Janjai, T. Jantarach, S.-C. Tsay, and W.K. Lau, 2013: Characterization of aerosols over the Indochina Peninsula from satellite-surface observations during biomass burning pre-monsoon season. *Atmospheric Environment*, **78**, 51-59.
- GAVI**, 2012: *GAVI Alliance Progress Report 2011*. GAVI Alliance, a health partnership of developing country and donor governments, the World Health Organization (WHO), the United Nations Children's Fund (UNICEF), the World Bank, the Bill & Melinda Gates Foundation, and other private philanthropists, GAVI Alliance, Geneva, Switzerland, 64 pp.
- Ge, Q.**, H. Wang, and J. Dai, 2013: Simulating changes in the leaf unfolding time of 20 plant species in China over the twenty-first century. *International Journal of Biometeorology*, doi:10.1007/s00484-013-0671-x.
- Gedan, K.B.**, M.L. Kirwan, E. Wolanski, E.B. Barbier, and B.R. Silliman, 2011: The present and future role of coastal wetland vegetation in protecting shorelines: answering recent challenges to the paradigm. *Climatic Change*, **106(1)**, 7-29.
- Gessner, U.**, V. Naeimi, I. Klein, C. Kuenzer, D. Klein, and S. Dech, 2013: The relationship between precipitation anomalies and satellite-derived vegetation activity in Central Asia. *Global and Planetary Change*, **10(Pt. A)**, 74-87.
- Gigli, S.** and S. Agrawala, 2007: *Stocktaking of Progress on Integrating Adaptation to Climate Change into Development Co-operation Activities*. COM/ENV/EPOC/DCD/DAC(2007)1/FINAL, Organization for Economic Co-operation and Development (OECD), Paris, France, 83 pp.
- Gilman, E.L.**, J. Ellison, N.C. Duke, and C. Field, 2008: Threats to mangroves from climate change and adaptation options: a review. *Aquatic Botany*, **89(2)**, 237-250.
- Giri, C.**, E. Ochieng, L.L. Tieszen, Z. Zhu, A. Singh, T. Loveland, J. Masek, and N. Duke, 2011: Status and distribution of mangrove forests of the world using earth observation satellite data. *Global Ecology and Biogeography*, **20(1)**, 154-159.
- Glazyrin, G.E.** and U.U. Tadzhibaeva, 2011: Climate change in the high mountains of Central Asia in the late 20th century. *Lёд i Sneg*, **114**, 12-15 (in Russian).
- Goetz, S.**, H. Epstein, U. Bhatt, G. Jia, J. Kaplan, H. Lischke, Q. Yu, A. Bunn, A. Lloyd, D. Alcaraz-Segura, P.A. Beck, J. Comiso, M. Reynolds, and D. Walker, 2011: Recent changes in Arctic vegetation: satellite observations and simulation model predictions. In: *Eurasian Arctic Land Cover and Land Use in a Changing Climate* [Gutman, G. and A. Reissell (eds.)]. Springer, Dordrecht, Netherlands, pp. 9-36.
- Golubyatnikov, L.L.** and E.A. Denisenko, 2007: Model estimates of climate change impact on habitats of zonal vegetation for the plain territories of Russia. *Biology Bulletin*, **34(2)**, 170-184.
- Green, E.P.** and F.T. Short, 2003: *World Atlas of Seagrasses*. United Nations Environment Programme, World Conservation Monitoring Centre (UNEP-WCMC), University of California Press, Berkeley, CA, USA, 298 pp.
- Griffin, D.W.**, 2007: Atmospheric movement of microorganisms in clouds of desert dust and implications for human health. *Clinical Microbiology Reviews*, **20(3)**, 459-477.
- Grigor'ev, A.A.**, P.A. Moiseev, and Z.Y. Nagimov, 2013: Dynamics of the timberline in high mountain areas of the Nether-Polar Urals under the influence of current climate change. *Russian Journal of Ecology*, **44(4)**, 312-323.
- Grumbine, R.E.**, J. Dore, and J. Xu, 2012: Mekong hydropower: drivers of change and governance challenges. *Frontiers in Ecology and the Environment*, **10(2)**, 91-98.
- Guan, D.** and K. Hubacek, 2007: Assessment of regional trade and virtual water flows in China. *Ecological Economics*, **61(1)**, 159-170.
- Guan, P.**, D. Huang, M. He, T. Shen, J. Guo, and B. Zhou, 2009: Investigating the effects of climatic variables and reservoir on the incidence of hemorrhagic fever with renal syndrome in Huludao City, China: a 17-year data analysis based on structure equation model. *BMC Infectious Diseases*, **9**, 109, doi:10.1186/1471-2334-9-109.
- Guariguata, M.R.**, J.P. Cornelius, B. Locatelli, C. Forner, and G.A. Sánchez-Azofeifa, 2008: Mitigation needs adaptation: tropical forestry and climate change. *Mitigation and Adaptation Strategies for Global Change*, **13(8)**, 793-808.
- Gumilang, H.**, K. Mukhopadhyay, and P.J. Thomassin, 2011: Economic and environmental impacts of trade liberalization: the case of Indonesia. *Economic Modelling*, **28(3)**, 1030-1041.
- Guo, Y.**, J. Wang, G. Li, Y. Zheng, W. He, and X. Pan, 2009: Association between ambient temperature and hospital emergency room visits for cardiovascular diseases: a case-crossover study. *Chinese Journal of Epidemiology*, **30(8)**, 810-815.
- Hadano, M.**, K.N. Nasahara, T. Motohka, H.M. Noda, K. Murakami, and M. Hosaka, 2013: High-resolution prediction of leaf onset date in Japan in the 21st century under the IPCC A1B scenario. *Ecology and Evolution*, **3(6)**, 1798-1807.
- Haggblade, S.**, P. Hazell, and T. Reardon, 2009: *Transforming the Rural Nonfarm Economy: Opportunities and Threats in the Developing World*. IFPRI Issue Brief 58, International Food Policy Research Institute (IFPRI), Washington, DC, USA, 4 pp.
- Haggblade, S.**, P. Hazell, and T. Reardon, 2010: The rural non-farm economy: prospects for growth and poverty reduction. *World Development*, **38(10)**, 1429-1441.
- Haghdooost, A.A.**, N. Alexander, and J. Cox, 2008: Modelling of malaria temporal variations in Iran. *Tropical Medicine & International Health*, **13(12)**, 1501-1508.
- Haines, A.**, A.J. McMichael, K.R. Smith, I. Roberts, J. Woodcock, A. Markandya, B.G. Armstrong, D. Campbell-Lendrum, A.D. Dangour, M. Davies, N. Bruce, C. Tonne, M. Barrett, and P. Wilkinson, 2009: Public health benefits of strategies to reduce greenhouse-gas emissions: overview and implications for policy makers. *Lancet*, **374(9707)**, 2104-2114.
- Hallegatte, S.** and J. Corfee-Morlot, 2011: Understanding climate change impacts, vulnerability and adaptation at city scale: an introduction. *Climatic Change*, **104(1)**, 1-12.

- Halls, A.S., 2009: Addressing fisheries in the Climate Change and Adaptation Initiative. *Catch and Culture: Fisheries Research and Development in the Mekong Region*, **15(1)**, 12-16.
- Hamilton, S.K., 2010: Biogeochemical implications of climate change for tropical rivers and floodplains. *Hydrobiologia*, **657(1)**, 19-35.
- Handmer, J., Y. Honda, Z.W. Kundzewicz, N. Arnell, G. Benito, J. Hatfield, I.F. Mohamed, P. Peduzzi, S. Wu, B. Sherstyukov, K. Takahashi, and Z. Yan, 2012: Changes in impacts of climate extremes: human systems and ecosystems. In: *Managing the Risks of Extreme Events and Disasters to Advanced Climate Change Adaptation. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change* [Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 231-290.
- Hannah, L., 2010: A global conservation system for climate-change adaptation. *Conservation Biology*, **24(1)**, 70-77.
- Hanson, S., R. Nicholls, N. Ranger, S. Hallegatte, J. Corfee-Morlot, C. Herweijer, and J. Chateau, 2011: A global ranking of port cities with high exposure to climate extremes. *Climatic Change*, **104(1)**, 89-111.
- Harris, A.M., F. Chowdhury, Y.A. Begum, A.I. Khan, A.S. Faruque, A.-M. Svennerholm, J.B. Harris, E.T. Ryan, A. Cravioto, and S.B. Calderwood, 2008: Shifting prevalence of major diarrheal pathogens in patients seeking hospital care during floods in 1998, 2004, and 2007 in Dhaka, Bangladesh. *American Journal of Tropical Medicine and Hygiene*, **79(5)**, 708-714.
- Harshita, T., 2013: Impact of drought on rice based agriculture economy – a case study of livelihood security in rural areas of Sultanpur District of Uttar Pradesh. *Voice of Intellectual Man – An International Journal*, **3(1)**, 137-148.
- Hashizume, M., B. Armstrong, S. Hajat, Y. Wagatsuma, A.S. Faruque, T. Hayashi, and D.A. Sack, 2007: Association between climate variability and hospital visits for non-cholera diarrhoea in Bangladesh: effects and vulnerable groups. *International Journal of Epidemiology*, **36(5)**, 1030-1037.
- Hashizume, M., Y. Wagatsuma, A.S.G. Faruque, T. Hayashi, P.R. Hunter, B. Armstrong, and D.A. Sack, 2008: Factors determining vulnerability to diarrhoea during and after severe floods in Bangladesh. *Journal of Water and Health*, **6(3)**, 323-332.
- Hashizume, M., Y. Wagatsuma, T. Hayashi, S.K. Saha, K. Streatfield, and M. Yunus, 2009: The effect of temperature on mortality in rural Bangladesh – a population-based time-series study. *International Journal of Epidemiology*, **38(6)**, 1689-1697.
- Hashizume, M., K. Ueda, Y. Nishiwaki, T. Michikawa, and D. Onozuka, 2010: Health effects of Asian dust events: a review of the literature. *Japanese Journal of Hygiene*, **65(3)**, 413-421.
- Hashizume, M., A. Faruque, T. Terao, M. Yunus, K. Streatfield, T. Yamamoto, and K. Moji, 2011: The Indian Ocean dipole and cholera incidence in Bangladesh: a time-series analysis. *Environmental Health Perspectives*, **119(2)**, 239-244.
- Hashizume, M., A.M. Dewan, T. Sunahara, M.Z. Rahman, and T. Yamamoto, 2012: Hydroclimatological variability and dengue transmission in Dhaka, Bangladesh: a time-series study. *BMC Infectious Diseases*, **12(1)**, 98, doi:10.1186/1471-2334-12-98.
- Heltberg, R., R. Prabhu, and H. Gitay, 2010: *Community-Based Adaptation: Lessons from the Development Marketplace 2009 on Adaptation to Climate Change*. Social Development Working Papers, Paper No. 122/June 2010, Social Development Department, The World Bank, Washington, DC, USA, 53 pp.
- Hertel, T.W., M.B. Burke, and D.B. Lobell, 2010: The poverty implications of climate-induced crop yield changes by 2030. *Global Environmental Change*, **20(4)**, 577-585.
- Higgins, S.I. and S. Scheiter, 2012: Atmospheric CO₂ forces abrupt vegetation shifts locally, but not globally. *Nature*, **488(7410)**, 209-212.
- Hii, Y.L., J. Rocklöv, N. Ng, C.S. Tang, F.Y. Pang, and R. Sauerborn, 2009: Climate aridity and increase in intensity and magnitude of dengue incidence in Singapore. *Global Health Action*, **2**, doi:10.3402/gha.v2i0.2036.
- Hoegh-Guldberg, O., 2011: Coral reef ecosystems and anthropogenic climate change. *Regional Environmental Change*, **11(1 Suppl.)** S215-S227.
- Honda, Y. and M. Ono, 2009: Issues in health risk assessment of current and future heat extremes. *Global Health Action*, **2**, doi:10.3402/gha.v2i0.2043.
- Hsieh, Y.H. and C. Chen, 2009: Turning points, reproduction number, and impact of climatological events for multi-wave dengue outbreaks. *Tropical Medicine & International Health*, **14(6)**, 628-638.
- Huang, D., G. Peng, G. Junqiao, W. Ping, and Z. Baosen, 2008: Investigating the effects of climate variations on bacillary dysentery incidence in northeast China using ridge regression and hierarchical cluster analysis. *BMC Infectious Diseases*, **8**, 130, doi:10.1186/1471-2334-8-130.
- Huang, W., H. Kan, and S. Kovats, 2010: The impact of the 2003 heat wave on mortality in Shanghai, China. *Science of the Total Environment*, **408(11)**, 2418-2420.
- Huang, X.-X., T.-J. Wang, F. Jiang, J.-B. Liao, Y.-F. Cai, C.-Q. Yin, J.-L. Zhu, and Y. Han, 2013: Studies on a severe dust storm in East Asia and its impact on the air quality of Nanjing, China. *Aerosol and Air Quality Research*, **13(1)**, 179-193.
- Hughes, A.C., C. Satasook, P.J.J. Bates, S. Bumrungsri, and G. Jones, 2012: The projected effects of climatic and vegetation changes on the distribution and diversity of Southeast Asian bats. *Global Change Biology*, **18(6)**, 1854-1865.
- Huigen, M.G.A. and I.C. Jens, 2006: Socio-economic impact of super typhoon Harurot in San Mariano, Isabela, the Philippines. *World Development*, **34(12)**, 2116-2136.
- Huq, A., R.B. Sack, A. Nizam, I.M. Longini, G.B. Nair, A. Ali, J.G. Morris, M.H. Khan, A.K. Siddique, and M. Yunus, 2005: Critical factors influencing the occurrence of *Vibrio cholerae* in the environment of Bangladesh. *Applied and Environmental Microbiology*, **71(8)**, 4645-4654.
- Huq, S.R. and H. Reid, 2007: *Community-Based Adaptation: A Vital Approach to the Threat Climate Change Poses to the Poor*. IIED Briefing, International Institute for Environment and Development (IIED), London, UK, 2 pp.
- Husain, T. and J.R. Chaudhary, 2008: Human health risk assessment due to global warming – a case study of the Gulf countries. *International Journal of Environmental Research and Public Health*, **5(4)**, 204-212.
- Hussain, S.S. and M. Mudasser, 2007: Prospects for wheat production under changing climate in mountain areas of Pakistan – an econometric analysis. *Agricultural Systems*, **94(2)**, 494-501.
- Hyatt, O.M., B. Lemke, and T. Kjellstrom, 2010: Regional maps of occupational heat exposure: past, present, and potential future. *Global Health Action*, **3**, doi:10.3402/gha.v3i0.5715.
- ICEM, 2010: *Climate Change Baseline Assessment Working Paper*. MRC Strategic Environmental Assessment (SEA) of Hydropower on the Mekong Mainstream, Vol. II: Baseline Assessment Working Papers, Prepared for the Mekong River Commission Secretariat (MRCS) by a consultant team that facilitated preparation of a Strategic Environment Assessment (SEA) of proposals for mainstream dams in the Lower Mekong Basin, International Centre for Environmental Management (ICEM), Hanoi, Vietnam, 51 pp.
- IDMC, 2011: *Displacement Due to Natural Hazard-Induced Disasters: Global Estimates for 2009 and 2010*. Internal Displacement Monitoring Centre (IDMC), Geneva, Switzerland, 30 pp.
- IFAD, 2010: *Rural Poverty Report 2011. New Realities, New Challenges: New Opportunities for Tomorrow's Generation*. International Fund for Agricultural Development (IFAD), Rome, Italy, 317 pp.
- Im, E.S., I.W. Jung, H. Chang, D.H. Bae, and W.T. Kwon, 2010: Hydroclimatological response to dynamically downscaled climate change simulations for Korean basins. *Climatic Change*, **100(3-4)**, 485-508.
- Immerzeel, W.W., L.P.H. Van Beek, and M.F.P. Bierkens, 2010: Climate change will affect the Asian water towers. *Science*, **328(5984)**, 1382-1385.
- Inсарov, G.E., O.K. Borisova, M.D. Korzukhin, V.N. Kudeyarov, A.A. Minin, A.V. Olchev, S.M. Semenov, A.A. Sirin, and V.I. Kharuk, 2012: Chapter 6: Terrestrial ecosystems. In: *Methods for Assessment of Climate Change Impacts on Physical and Biological Systems* [Semenov, S.M. (ed.)]. Planet Publishing, Moscow, Russia, pp. 190-265.
- IPCC, 2007: *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on the Climate Change* [Parry, M.L., O.F. Canziani, J.P. Palutikof, P.J. van der Linden, and C.E. Hanson (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, 976 pp.
- IPCC, 2012: *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change* [Field, C.B., V. Barros, T.F. Stocker, Q. Dahe, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, 582 pp.
- Iqbal, M.M., M.A. Goheer, and A.M. Khan, 2009: Climate change aspersions on food security of Pakistan. *Science Vision*, **15(1)**, 15-23.
- IRG, 2010: *USAID Asia-Pacific Regional Climate Change Needs Assessment. Final Report: Findings and Recommendations*. International Resources Group (IRG), Washington, DC, USA, 135 pp.
- Ishizuka, W. and S. Goto, 2012: Modeling intraspecific adaptation of *Abies sachalinensis* to local altitude and responses to global warming, based on a 36-year reciprocal transplant experiment. *Evolutionary Applications*, **5(3)**, 229-244.

- Islam, M.K., J. Merlo, I. Kawachi, M. Lindström, and U.-G. Gerdtham, 2006: Social capital and health: does egalitarianism matter? A literature review. *International Journal for Equity in Health*, **5**(1), 3, doi:10.1186/1475-9276-5-3.
- IUCN, 2009: *Ecosystem-Based Adaptation: A Natural Response to Climate Change*. International Union for the Conservation of Nature (IUCN), Gland, Switzerland, 16 pp.
- Iwasaki, S., B.H.N. Razafindrabe, and R. Shaw, 2009: Fishery livelihoods and adaptation to climate change: a case study of Chilika lagoon, India. *Mitigation and Adaptation Strategies for Global Change*, **14**(4), 339-355.
- Janvry, A. and E. Sadoulet, 2010: Agricultural growth and poverty reduction: additional evidence. *The World Bank Research Observer*, **25**(1), 1-20.
- Jarvis, A., C. Lau, S. Cook, E. Wollenberg, J. Hansen, O. Bonilla, and A. Challinor, 2011: An integrated adaptation and mitigation framework for developing agricultural research: synergies and tradeoffs. *Experimental Agriculture*, **47**, 185-203.
- Jasparro, C. and J. Taylor, 2008: Climate change and regional vulnerability to transnational security threats in Southeast Asia. *Geopolitics*, **13**(2), 232-256.
- Jeong, S.-J., C.-H. Ho, B.-M. Kim, S. Feng, and D. Medvigy, 2013: Non-linear response of vegetation to coherent warming over northern high latitudes. *Remote Sensing Letters*, **4**(2), 123-130.
- Jevanandam, N., A.G.R. Goh, and R.T. Corlett, 2013: Climate warming and the potential extinction of fig wasps, the obligate pollinators of figs. *Biology Letters*, **9**(3), 20130041, doi: 10.1098/rsbl.2013.0041.
- Jian, J., P.J. Webster, and C.D. Hoyos, 2009: Large-scale controls on Ganges and Brahmaputra river discharge on intraseasonal and seasonal time-scales. *Quarterly Journal of the Royal Meteorological Society*, **135**(639), 353-370.
- Jin, Z., Q. Zhuang, J.-S. He, T. Luo, and Y. Shi, 2013: Phenology shift from 1989 to 2008 on the Tibetan Plateau: an analysis with a process-based soil physical model and remote sensing data. *Climatic Change*, **119**(2), 435-449.
- Johnston, F.H., S.B. Henderson, Y. Chen, J.T. Randerson, M. Marlier, R.S. DeFries, P. Kinney, D.M. Bowman, and M. Brauer, 2012: Estimated global mortality attributable to smoke from landscape fires. *Environmental Health Perspectives*, **120**(5), 695-701.
- Jones, H.P., D.G. Hole, and E.S. Zavaleta, 2012: Harnessing nature to help people adapt to climate change. *Nature Climate Change*, **2**, 504-509.
- Jones, L. and E. Boyd, 2011: Exploring social barriers to adaptation: insights from Western Nepal. *Global Environmental Change* **21**(1), 1262-1274.
- Joubert, D., J. Thomsen, and O. Harrison, 2011: Safety in the heat: a comprehensive program for prevention of heat illness among workers in Abu Dhabi, United Arab Emirates. *American Journal of Public Health*, **101**(3), 395-398.
- Jump, A.S., T.J. Huang, and C.H. Chou, 2012: Rapid altitudinal migration of mountain plants in Taiwan and its implications for high altitude biodiversity. *Ecography*, **35**(3), 204-210.
- Kan, H., S.J. London, H. Chen, G. Song, G. Chen, L. Jiang, N. Zhao, Y. Zhang, and B. Chen, 2007: Diurnal temperature range and daily mortality in Shanghai, China. *Environmental Research*, **103**(3), 424-431.
- Kan, H., R. Chen, and S. Tong, 2012: Ambient air pollution, climate change, and population health in China. *Environment International*, **42**, 10-19.
- Kang, S., B. Yang, and C. Qin, 2012: Recent tree-growth reduction in north central China as a combined result of a weakened monsoon and atmospheric oscillations. *Climatic Change*, **115**(3-4), 519-536.
- Kaplan, J.O. and M. New, 2006: Arctic climate change with a 2 degrees C global warming: timing, climate patterns and vegetation change. *Climatic Change*, **79**(3-4), 213-241.
- Karim, M.F. and N. Mimura, 2008: Impacts of climate change and sea-level rise on cyclonic storm surge floods in Bangladesh. *Global Environmental Change*, **18**(3), 490-500.
- Kariyeva, J., W.D. Leeuwen, and C. Woodhouse, 2012: Impacts of climate gradients on the vegetation phenology of major land use types in Central Asia (1981-2008). *Frontiers of Earth Science*, **6**(2), 206-225.
- Kawaguchi, L., B. Sengkeopraseth, R. Tsuyuoka, N. Koizumi, H. Akashi, P. Vongphrachanh, H. Watanabe, and A. Aoyama, 2008: Seroprevalence of leptospirosis and risk factor analysis in flood-prone rural areas in Lao PDR. *American Journal of Tropical Medicine and Hygiene*, **78**(6), 957-961.
- Kazama, S., T. Aizawa, T. Watanabe, P. Ranjan, L. Gunawardhana, and A. Amano, 2012: A quantitative risk assessment of waterborne infectious disease in the inundation area of a tropical monsoon region. *Sustainability Science*, **7**(1), 45-54.
- Kelkar, U., K.K. Narula, V.P. Sharma, and U. Chandna, 2008: Vulnerability and adaptation to climate variability and water stress in Uttarakhand State, India. *Global Environmental Change*, **18**(4), 564-574.
- Keskinen, M.C., S. Kumm, M. Nuorteva, P. Snidvongs, A. Varis, and O. Vastila, K., 2010: Climate change and water resources in the Lower Mekong River Basin: putting adaptation into context. *Journal of Water and Climate Change*, **1**(2), 103-117.
- Kharuk, V.I., K.J. Ranson, S.T. Im, and M.M. Naurzbaev, 2006: Forest-tundra larch forests and climatic trends. *Russian Journal of Ecology*, **37**(5), 291-298.
- Kharuk, V.I., S.T. Im, and M.L. Dvinskaya, 2010a: Forest-tundra ecotone response to climate change in the Western Sayan Mountains, Siberia. *Scandinavian Journal of Forest Research*, **25**(3), 224-233.
- Kharuk, V.I., S.T. Im, M.L. Dvinskaya, and K.J. Ranson, 2010b: Climate-induced mountain tree-line evolution in southern Siberia. *Scandinavian Journal of Forest Research*, **25**(5), 446-454.
- Kharuk, V.I., K.J. Ranson, and M.L. Dvinskaya, 2010c: Evidence of evergreen conifers invasion into larch dominated forests during recent decades. In: *Environmental Change in Siberia: Earth Observation, Field Studies and Modelling* [Balzter, H. (ed.)]. Springer, Dordrecht, Netherlands, pp. 53-65.
- Kharuk, V.I., K.J. Ranson, M.L. Dvinskaya, and S.T. Im, 2010d: Siberian pine and larch response to climate warming in the southern Siberian mountain forest: tundra ecotone. In: *Environmental Change in Siberia: Earth Observation, Field Studies and Modelling* [Balzter, H. (ed.)]. Springer, Dordrecht, Netherlands, pp. 115-132.
- Kharuk, V.I., K.J. Ranson, S.T. Im, and A.S. Vdovin, 2010e: Spatial distribution and temporal dynamics of high-elevation forest stands in southern Siberia. *Global Ecology and Biogeography*, **19**(6), 822-830.
- Kharuk, V.I., K.J. Ranson, P.A. Oskorbin, S.T. Im, and M.L. Dvinskaya, 2013: Climate induced birch mortality in Trans-Baikal lake region, Siberia. *Forest Ecology and Management*, **289**, 385-392.
- Khair, S., A. Alahmed, M. Al Kuriji, and S.F. Al Zubayni, 2010: Distribution and seasonal activity of mosquitoes in Al Madinah Al Munawwrah, Saudi Arabia. *Journal of the Egyptian Society of Parasitology*, **40**(1), 215-227.
- Khim, L. and H. Phearanch, 2012: Climate resilience in rural Cambodia: adaptation mainstreaming, water resource management and agricultural practice. *Asian Journal of Environment and Disaster Risk Management*, **4**(4 SI), 447-468.
- Kim, B.S., H.S. Kim, B.H. Seoh, and N.W. Kim, 2007: Impact of climate change on water resources in Yongdam Dam Basin, Korea. *Stochastic Environmental Research and Risk Assessment*, **21**(4), 355-373.
- Kim, H., J.-S. Ha, and J. Park, 2006: High temperature, heat index, and mortality in 6 major cities in South Korea. *Archives of Environmental & Occupational Health*, **61**(6), 265-270.
- Kim Oanh, N.T. and K. Leelasakultum, 2011: Analysis of meteorology and emission in haze episode prevalence over mountain-bounded region for early warning. *Science of the Total Environment*, **409**(11), 2261-2271.
- Kim, S.-H. and J.-Y. Jang, 2010: Correlations between climate change-related infectious diseases and meteorological factors in Korea. *Journal of Preventive Medicine and Public Health*, **43**(5), 436-444.
- Kintisch, E., 2013: Can coastal marshes rise above it all? *Science*, **341**(6145), 480-481.
- Klein, R.J.T., S. Huq, F. Denton, T.E. Downing, R.G. Richels, J.B. Robinson, and F.L. Toth, 2007: Inter-relationships between adaptation and mitigation. In: *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Parry, M.L., O.F. Canziani, J.P. Palutikof, P.J. van der Linden, and C.E. Hanson (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 745-777.
- Klorvuttimontara, S., C.J. McClean, and J.K. Hill, 2011: Evaluating the effectiveness of Protected Areas for conserving tropical forest butterflies of Thailand. *Biological Conservation*, **144**(10), 2534-2540.
- Knox, J.W., T.M. Hess, A. Daccache, and M.P. Ortola, 2011: *What are the Projected Impacts of Climate Change on Food Crop Productivity in Africa and South Asia?* Department for International Development (DFID), Systematic Review, Final Report, produced for DFID by Canfield University, DFID, London, UK, 71 pp.
- Knox, J., T. Hess, A. Daccache, and T. Wheeler, 2012: Climate change impacts on crop productivity in Africa and South Asia. *Environmental Research Letters*, **7**(3), 034032, doi:10.1088/1748-9326/7/3/034032.
- Knutson, T.R., J.L. McBride, J. Chan, K. Emanuel, G. Holland, C. Landsea, I. Held, J.P. Kossin, A.K. Srivastava, and M. Sugi, 2010: Tropical cyclones and climate change. *Nature Geoscience*, **3**(3), 157-163.
- Ko, C.Y., T.L. Root, S.H. Lin, S.H. Schneider, and P.F. Lee, 2012: Global change projections for Taiwan island birds: linking current and future distributions. *Nature Conservation*, **2**, 21-40.

- Kolmannskog, V.O.**, 2008: *Future Floods of Refugees: A Comment on Climate Change, Conflict and Forced Migration*. Norwegian Refugee Council, Oslo, Norway, 42 pp.
- Konovalov, V.** and L. Desinov, 2007: Remote sensing monitoring of the long-term regime of the Pamirs glaciers. *International Association of Hydrological Sciences Publications*, **316**, 149-156.
- Korzukhin, M.D.** and Y.L. Tselniker, 2010: Model analysis of present ranges for forest tree species in Russia and their changes under two climatic scenarios. *Problems of Ecological Monitoring and Ecosystem Modelling*, **23**, 249-268.
- Kostianoy, A.G.** and A.N. Kosarev, 2010: *The Aral Sea Environment*. Handbook of Environmental Chemistry, Vol. 7, 1st edn., Springer, Berlin and Heidelberg, Germany, 332 pp.
- Kranz, N.**, T. Menniken, and J. Hinkel, 2010: Climate change adaptation strategies in the Mekong and Orange-Senqu basins: what determines the state-of-play? *Environmental Science & Policy*, **13(7)**, 648-659.
- Kroeker, K.J.**, R.L. Kordas, R. Crim, I.E. Hendriks, L. Ramajo, G.S. Singh, C.M. Duarte, and J.-P. Gattuso, 2013: Impacts of ocean acidification on marine organisms: quantifying sensitivities and interaction with warming. *Global Change Biology*, **19(6)**, 1884-1896.
- Kukavskaya, E.A.**, A.J. Soja, A.P. Petkov, E.I. Ponomarev, G.A. Ivanova, and S.G. Conard, 2013: Fire emissions estimates in Siberia: evaluation of uncertainties in area burned, land cover, and fuel consumption. *Canadian Journal of Forest Research*, **43(5)**, 493-506.
- Kumagai, T.** and A. Porporato, 2012: Drought-induced mortality of a Bornean tropical rain forest amplified by climate change. *Journal of Geophysical Research: Biogeosciences*, **117(G2)**, G02032, doi:10.1029/2011JG001835.
- Kumar, R.H.**, K. Venkaiah, N. Arlappa, S. Kumar, G. Brahman, and K. Vijayaraghavan, 2005: Diet and nutritional situation of the population in the severely drought affected areas of Gujarat. *Journal of Human Ecology*, **18(4)**, 319-326.
- Kumpula, T.**, A. Pajunen, E. Kaarlejarvi, B.C. Forbes, and F. Stammer, 2011: Land use and land cover change in Arctic Russia: ecological and social implications of industrial development. *Global Environmental Change*, **21**, 550-562.
- La Sorte, F.A.** and W. Jetz, 2010: Projected range contractions of montane biodiversity under global warming. *Proceedings of the Royal Society B*, **277(1699)**, 3401-3410.
- Laczko, F.** and C. Aghazarm, 2009: *Migration, Environment and Climate Change: Assessing the Evidence*. International Organization for Migration (IOM), Geneva, Switzerland, 441 pp.
- Lal, M.**, 2011: Implications of climate change in sustained agricultural productivity in South Asia. *Regional Environmental Change*, **11**, S79-S94.
- Laneri, K.**, A. Bhadra, E.L. Ionides, M. Bouma, R.C. Dhiman, R.S. Yadav, and M. Pascual, 2010: Forcing versus feedback: epidemic malaria and monsoon rains in northwest India. *PLoS Computational Biology*, **6(9)**, e1000898, doi:10.1371/journal.pcbi.1000898.
- Langkulsen, U.**, N. Vichit-Vadakan, and S. Taptagaporn, 2010: Health impact of climate change on occupational health and productivity in Thailand. *Global Health Action*, **3**, 5607, doi:10.3402/gha.v3i0.5607.
- Lantuit, H.**, P.P. Overduin, N. Couture, S. Wetterich, F. Aré, D. Atkinson, J. Brown, G. Cherkashov, D. Drozdov, D.L. Forbes, A. Graves-Gaylord, M. Grigoriev, H.-W. Hubberten, J. Jordan, T. Jorgenson, R.S. Ødegård, S. Ogorodov, W.H. Pollard, V. Rachold, S. Sedenko, S. Solomon, F. Steenhuisen, I. Streletskaia, and A. Vasiliiev, 2012: The Arctic Coastal Dynamics Database: a new classification scheme and statistics on Arctic permafrost coastlines. *Estuaries and Coasts*, **35(2)**, 383-400.
- Larson, A.M.**, 2011: Forest tenure reform in the age of climate change: lessons for REDD+. *Global Environmental Change*, **21**, 540-549.
- Lasco, R.D.**, F.B. Pulhin, P.A. Jaranilla-Sanchez, R.J.P. Delfino, R. Gerpacio, and K. Garcia, 2009: Mainstreaming adaptation in developing countries: the case of the Philippines. *Climate and Development*, **1(2)**, 130-146.
- Lasco, R.D.**, R.V.O. Cruz, J.M. Pulhin, and F.B. Pulhin, 2010: *Assessing Impacts, Vulnerability and Adaptation: The Case of Pantabangan-Carranglan Watershed*. Nova Science Publishers, New York, NY, USA, 167 pp.
- Lasco, R.D.**, C.M.D. Habito, R.J.P. Delfino, F.B. Pulhin, and R.N. Concepcion, 2011: *Climate Change Adaptation for Smallholder Farmers in Southeast Asia*. World Agroforestry Centre, Laguna, Philippines, 65 pp.
- Lasco, R.D.**, R.J. Delfino, M. Rangasa, and F.B. Pulhin, 2012: The role of local government units in mainstreaming climate change adaptation: the case of Albay, Philippines. In: *Local Climate Change and Society* [Salih, M.A.M. (ed.)]. Routledge, London, UK and New York, NY, USA, pp. 45-73.
- Label, L.**, L. Li, C. Krittasudthacheewa, M. Juntopas, T. Vijiapan, T. Uchiyama, and D. Krawanchid, 2012: *Mainstreaming Climate Change Adaptation into Development Planning*. Adaptation Knowledge Platform and Stockholm Environment Institute (SEI), Bangkok, Thailand, 25 pp.
- Lee, I.-M.**, S.-S. Tsai, C.-K. Ho, H.-F. Chiu, and C.Y. Yang, 2007: Air pollution and hospital admissions for congestive heart failure in a tropical city: Kaohsiung, Taiwan. *Inhalation Toxicology*, **19(10)**, 899-904.
- Lettenmaier, D.P.**, V. Aizen, A. Amani, T. Bohn, F. Giorgi, S. Harrison, T.G. Huntington, R. Lawford, P. Letitre, H. Lins, J. Magomi, G.-K. Park, I. Severskiy, W.J. Shuttleworth, P. Singh, S. Sorooshian, W. Struckmeier, K. Takeuchi, L. Tallaksen, C. Vörösmarty, T. Yan, and T. Zhang, 2009: Changes in the global water cycle. In: *The United Nations World Water Development Report 3: Water in a Changing World*. Report published on behalf of the World Water Assessment Programme by the United Nations Educational, Scientific and Cultural Organization (UNESCO), Paris, France and Earthscan, London, UK, pp. 181-225.
- Levy, J.S.** and N.C. Ban, 2013: A method for incorporating climate change modelling into marine conservation planning: an Indo-west Pacific example. *Marine Policy*, **38**, 16-24.
- Li, H.**, 2008: The more severe climate change, the greater the negative impact. *China Forestry Industry*, **4**, 60-63.
- Li, J.**, X. Gou, E.R. Cook, and F. Chen, 2006: Tree-ring based drought reconstruction for the central Tien Shan area in northwest China. *Geophysical Research Letters*, **33(7)**, L07715, doi:10.1029/2006GL025803.
- Li, J.**, F. Chen, E.R. Cook, X. Gou, and Y. Zhang, 2007: Drought reconstruction for north central China from tree rings: the value of the Palmer drought severity index. *International Journal of Climatology*, **27(7)**, 903-909.
- Li, R.**, H. Tian, and X. Li, 2010: Climate change induced range shifts of Galliformes in China. *Integrative Zoology*, **5(2)**, 154-163.
- Li, X.**, G. Cheng, H. Jin, E. Kang, T. Che, R. Jin, L. Wu, Z. Nan, J. Wang, and Y. Shen, 2008: Cryospheric change in China. *Global and Planetary Change*, **62(3-4)**, 210-218.
- Li, X.**, H.S. He, Z. Wu, Y. Liang, and J.E. Schneiderman, 2013: Comparing effects of climate warming, fire, and timber harvesting on a boreal forest landscape in Northeastern China. *PLoS ONE*, **8(4)**, e59747, doi:10.1371/journal.pone.0059747.
- Li, Z.**, Y. He, T. Pu, W. Jia, X. He, H. Pang, N. Zhang, Q. Liu, S. Wang, G. Zhu, S. Wang, L. Chang, J. Du, and H. Xin, 2010: Changes of climate, glaciers, and runoff in China's monsoonal temperate glacier region during the last several decades. *Quaternary International*, **218(1-2)**, 13-28.
- Li, Z.-S.**, Q.-B. Zhang, and K. Ma, 2012: Tree-ring reconstruction of summer temperature for A.D. 1475-2003 in the central Hengduan Mountains, northwestern Yunnan, China. *Climatic Change*, **110(1)**, 455-467.
- Lian, K.K.** and L. Bhullar, 2011: Governance on adaptation to climate change in the Asean Region. *Carbon and Climate Change Law Review*, **5(1)**, 82-90.
- Liancourt, P.**, L.A. Spence, B. Boldgiv, A. Lkhagva, B.R. Helliker, B.B. Casper, and P.S. Petraitis, 2012: Vulnerability of the northern Mongolian steppe to climate change: insights from flower production and phenology. *Ecology*, **93(4)**, 815-824.
- Liang, T.**, Q. Feng, H. Yu, X. Huang, H. Lin, S. An, and J. Ren, 2012: Dynamics of natural vegetation on the Tibetan Plateau from past to future using a comprehensive and sequential classification system and remote sensing data. *Grassland Science*, **58(4)**, 208-220.
- Lim, B.**, E. Spanger-Siegfried, I. Burton, E. Malone, and S. Huq (eds.), 2005: *Adaptation Policy Frameworks for Climate Change: Developing Strategies, Policies and Measures*. Cambridge University Press, New York, NY, USA, 258 pp.
- Lin, H.**, B. Xu, Y. Chen, and W. Wang, 2009: Legionella pollution in cooling tower water of air-conditioning systems in Shanghai, China. *Journal of Applied Microbiology*, **106(2)**, 606-612.
- Lioubimtseva, E.** and G.M. Henebry, 2009: Climate and environmental change in arid Central Asia: impacts, vulnerability, and adaptations. *Journal of Arid Environments*, **73(11)**, 963-977.
- Liu, H.**, C.-L. Feng, Y.-B. Luo, B.-S. Chen, Z.-S. Wang, and H.-Y. Gu, 2010: Potential challenges of climate change to orchid conservation in a wild orchid hotspot in Southwestern China. *Botanical Review*, **76(2)**, 174-192.
- Liu, H.**, F. Tian, H.C. Hu, H.P. Hu, and M. Sivapalan, 2013a: Soil moisture controls on patterns of grass green-up in Inner Mongolia: an index based approach. *Hydrology and Earth System Sciences*, **17(2)**, 805-815.
- Liu, H.**, A. Park Williams, C.D. Allen, D. Guo, X. Wu, O.A. Anenkhonov, E. Liang, D.V. Sandanov, Y. Yin, Z. Qi, and N.K. Badmaeva, 2013b: Rapid warming accelerates tree growth decline in semi-arid forests of Inner Asia. *Global Change Biology*, **19(8)**, 2500-2510.

- Liu, Z., J. Yang, Y. Chang, P.J. Weisberg, and H.S. He, 2012: Spatial patterns and drivers of fire occurrence and its future trend under climate change in a boreal forest of Northeast China. *Global Change Biology*, **18**(6), 2041-2056.
- Lloyd, A.H. and A.G. Bunn, 2007: Responses of the circumpolar boreal forest to 20th century climate variability. *Environmental Research Letters*, **2**(4), 045013, doi:10.1088/1748-9326/2/4/045013.
- Lloyd, A.H., A.G. Bunn, and L. Berner, 2011: A latitudinal gradient in tree growth response to climate warming in the Siberian taiga. *Global Change Biology*, **17**(5), 1935-1945.
- Loucks, C., S. Barber-Meyer, M. Hossain, A. Barlow, and R. Chowdhury, 2010: Sea level rise and tigers: predicted impacts to Bangladesh's Sundarbans mangroves. *Climatic Change*, **98**(1-2), 291-298.
- Lucht, W., S. Schaphoff, T. Erbrecht, U. Heyder, and W. Cramer, 2006: Terrestrial vegetation redistribution and carbon balance under climate change. *Carbon Balance and Management*, **1**, 6, doi:10.1186/1750-0680-1-6.
- Macchi, M., G. Oviedo, S. Gotheil, K. Cross, A. Boedihartono, C. Wolfangel, and M. Howell, 2008: *Indigenous and Traditional Peoples and Climate Change*. Int'l Union for Conservation of Nature (IUCN), Gland, Switzerland, 66 pp.
- Mainuddin, M., M. Kirby, and C.T. Hoanh, 2011: Adaptation to climate change for food security in the lower Mekong Basin. *Food Security*, **3**(4), 433-450.
- Majra, J. and A. Gur, 2009: Climate change and health: why should India be concerned? *Indian Journal of Occupational and Environmental Medicine*, **13**(1), 11-16.
- Mandych, A.F., T.V. Yashina, I.A. Artemov, V.V. Dekenov, G.E. Insarov, O.V. Ostanin, I.N. Rotanova, M.G. Sukhova, N.F. Kharlamova, A.S. Shishikin, and A.B. Shmakin, 2012: *Biodiversity Conservation in the Russian Portion of the Altai-Sayan Ecoregion under Climate Change. Adaptation Strategy*. Gorod Publishing House, Krasnoyarsk, Russia, 62 pp.
- Marchenko, S.S., A.P. Gorbunov, and V.E. Romanovsky, 2007: Permafrost warming in the Tien Shan Mountains, Central Asia. *Global and Planetary Change*, **56**(3-4), 311-327.
- Markandya, A., B.G. Armstrong, S. Hales, A. Chiabai, P. Criqui, S. Mima, C. Tonne, and P. Wilkinson, 2009: Public health benefits of strategies to reduce greenhouse-gas emissions: low-carbon electricity generation. *Lancet*, **374**(9706), 2006-2015.
- Marques, A., M.L. Nunes, S.K. Moore, and M.S. Strom, 2010: Climate change and seafood safety: human health implications. *Food Research International*, **43**(7), 1766-1779.
- Marzeion, B., A.H. Jarosch, and M. Hofer, 2012: Past and future sea-level change from the surface mass balance of glaciers. *Cryosphere*, **6**(6), 1295-1322.
- Masutomi, Y., K. Takahashi, H. Harasawa, and Y. Matsuoka, 2009: Impact assessment of climate change on rice production in Asia in comprehensive consideration of process/parameter uncertainty in general circulation models. *Agriculture, Ecosystems & Environment*, **131**(3-4), 281-291.
- Mathy, S. and C. Guivarch, 2010: Climate policies in a second-best world – a case study on India. *Energy Policy*, **38**, 1519-1528.
- Mattoo, A. and A. Subramanian, 2012: Equity in climate change: an analytical review. *World Development*, **40**(6), 1083-1097.
- Maxwell, J.F., 2009: Vegetation and vascular flora of the Mekong River, Kratie and Steung Treng Provinces, Cambodia. *Maejo International Journal of Science and Technology*, **3**(1), 143-211.
- McClanahan, T.R., S.D. Donner, J.A. Maynard, M.A. MacNeil, N.A.J. Graham, J. Maina, A.C. Baker, J.B.I. Alemu, M. Beger, S.J. Campbell, E.S. Darling, C.M. Eakin, S.F. Heron, S.D. Jupiter, C.J. Lundquist, E. McLeod, P.J. Mumby, M.J. Paddock, E.R. Selig, and R. van Woesik, 2012: Prioritizing key resilience indicators to support coral reef management in a changing climate. *PLoS ONE*, **7**(8), e42884, doi:10.1371/journal.pone.0042884.
- McConkey, K.R., S. Prasad, R.T. Corlett, A. Campos-Arceiz, J.F. Brodie, H. Rogers, and L. Santamaria, 2012: Seed dispersal in changing landscapes. *Biological Conservation*, **146**(1), 1-13.
- McGuire, A.D., F.S. Chapin, C. Wirth, M. Apps, J. Bhatti, T. Callaghan, T.R. Christensen, J.S. Clein, M. Fukuda, T. Maximov, A. Onuchin, A. Shvidenko, and E.A. Vaganov, 2007: Responses of high latitude ecosystems to global change: potential consequences for the climate system. In: *Terrestrial Ecosystems in a Changing World* [Canadell, J.G., D.E. Pataki, and L.F. Pitelka (eds.)]. Springer, Berlin, Germany, pp. 297-310.
- McLeod, E., K.R.N. Anthony, A. Andersson, R. Beeden, Y. Golbuu, J. Kleypas, K. Kroeker, D. Manzello, R.V. Salm, H. Schuttenberg, and J.E. Smith, 2013: Preparing to manage coral reefs for ocean acidification: lessons from coral bleaching. *Frontiers in Ecology and the Environment*, **11**(1), 20-27.
- McMichael, A.J., P. Wilkinson, R.S. Kovats, S. Pattenden, S. Hajat, B. Armstrong, N. Vajanapoom, E.M. Niciu, H. Mahomed, and C. Kingkeow, 2008: International study of temperature, heat and urban mortality: the 'ISOTHERM' project. *International Journal of Epidemiology*, **37**(5), 1121-1131.
- Mearns, R. and A. Norton, 2010: *Social Dimensions of Climate Change: Equity and Vulnerability in a Warming World*. New Frontiers of Social Policy 52097, The World Bank, Washington, DC, USA, 319 pp.
- Meleshko, V.P. and S.M. Semenov, 2008: *Assessment Report on Climate Change and Its Consequences in the Russian Federation: General Summary*. Federal Service for Hydrometeorology and Environmental Monitoring of Russia (Roshydromet), RIHMI-WDC, Obninsk, Kaluga region, Russia, 24 pp.
- Menon, S., M.Z. Islam, and A.T. Peterson, 2009: Projected climate change effects on nuthatch distribution and diversity across Asia. *Raffles Bulletin of Zoology*, **57**(2), 569-575.
- Merrey, D.J., P. Drechsel, F.W.P. de Vries, and H. Sally, 2005: Integrating "livelihoods" into integrated water resources management: taking the integration paradigm to its logical next step for developing countries. *Regional Environmental Change*, **5**(4), 197-204.
- Miettinen, J., C. Shi, and S.C. Liew, 2011a: Deforestation rates in insular Southeast Asia between 2000 and 2010. *Global Change Biology*, **17**(7), 2261-2270.
- Miettinen, J., C.H. Shi, and S.C. Liew, 2011b: Influence of peatland and land cover distribution on fire regimes in insular Southeast Asia. *Regional Environmental Change*, **11**(1), 191-201.
- MNRE, 2010: *Malaysia: Second National Communication to the UNFCCC*. Report is Malaysia's Second National Communication (NC2) submitted to the United Nations Framework Convention on Climate Change (UNFCCC), Ministry of Natural Resources and Environment (MNRE), Putrajaya, Malaysia, 145 pp.
- Moench, M., 2010: Responding to climate and other change processes in complex contexts: challenges facing development of adaptive policy frameworks in the Ganga Basin. *Technological Forecasting and Social Change*, **77**(6), 975-986.
- Mohammad, A., X. Wang, X. Xu, L. Peng, Y. Yang, X. Zhang, R.B. Myneni, and S. Piao, 2013: Drought and spring cooling induced recent decrease in vegetation growth in Inner Asia. *Agricultural and Forest Meteorology*, **178**, 21-30.
- Mohammed, A.R. and L. Tarpley, 2009: High nighttime temperatures affect rice productivity through altered pollen germination and spikelet fertility. *Agricultural and Forest Meteorology*, **149**(6-7), 999-1008.
- Moiseev, P.A., A.A. Bartysh, and Z.Y. Nagimov, 2010: Climate changes and tree stand dynamics at the upper limit of their growth in the North Ural mountains. *Russian Journal of Ecology*, **41**(6), 486-497.
- Molle, F. and C.T. Hoanh, 2009: *Implementing Integrated River Basin Management: Lessons from the Red River Basin, Vietnam*. IWMI Research Report 131, International Water Management Institute (IWMI), Colombo, Sri Lanka, 25 pp.
- Mondal, P., 2012: Baseline assessments, vulnerability analysis and finding sustainable livelihood options: designing a climate change adaptation project in Ben Tre province, Vietnam. *Asian Journal of Environment and Disaster Risk Management*, **4**(4), 485-504.
- Morioka, I., N. Miyai, and K. Miyashita, 2006: Hot environment and health problems of outdoor workers at a construction site. *Industrial Health*, **44**(3), 474-480.
- Moser, S.C. and J.A. Ekstrom, 2010: A framework to diagnose barriers to climate change adaptation. *Proceedings of the National Academy of Sciences of the United States of America*, **107**(51), 22026-22031.
- MRC, 2009: *Adaptation to Climate Change in the Countries of the Lower Mekong Basin: Regional Synthesis Report*. MRC Technical Paper No. 24, Mekong River Commission (MRC), Vientiane, Laos, 89 pp.
- Mulligan, M., M. Fisher, B. Sharma, Z. Xu, C. Ringler, G. Mahé, A. Jarvis, J. Ramirez, J.-C. Claret, and A. Ogilvie, 2011: The nature and impact of climate change in the Challenge Program on Water and Food (CPWF) basins. *Water International*, **36**(1), 96-124.
- Mumby, H.S., A. Courtiol, K.U. Mar, and V. Lummaa, 2013: Climatic variation and age-specific survival in Asian elephants from Myanmar. *Ecology*, **94**(5), 1131-1141.
- Munslow, B. and T. O'Dempsey, 2010: Globalisation and climate change in Asia: the urban health impact. *Third World Quarterly*, **31**(8), 1339-1356.
- Murdiyarsa, D. and L. Lebel, 2007: Local to global perspectives on forest and land fires in Southeast Asia. *Mitigation and Adaptation Strategies for Global Change*, **12**(1), 3-11.
- Murphy, T.I. and M. K. Sampson, 2013: The stress of climate change on water management in Cambodia with a focus on rice production. *Climate and Development*, **5**(1), 77-92.

- Murthy, I.K., R. Tiwari, and N.H. Ravindranath, 2011:** Climate change and forests in India: adaptation opportunities and challenges. *Mitigation and Adaptation Strategies for Global Change*, **16(2)**, 161-175.
- Murty, U.S., M.S. Rao, and N. Arunachalam, 2010:** The effects of climatic factors on the distribution and abundance of Japanese encephalitis vectors in Kurnool district of Andhra Pradesh, India. *Journal of Vector Borne Diseases*, **47(1)**, 26-32.
- Myers-Smith, I.H., D.S. Hik, C. Kennedy, D. Cooley, J.F. Johnstone, A.J. Kenney, and C.J. Krebs, 2011:** Expansion of canopy-forming willows over the twentieth century on Herschel Island, Yukon Territory, Canada. *AMBIO: A Journal of the Human Environment*, **40(6)**, 610-623.
- Nadyozhina, E.D., T.V. Pavlova, I.M. Shkolnik, E.K. Molkentin, and A.A. Semioshina, 2010:** Simulation of snowcover and permafrost in Russia. *Earth Cryosphere*, **2**, 87-97.
- Nag, P.K., A. Nag, and S.P. Ashtekar, 2007:** Thermal limits of men in moderate to heavy work in tropical farming. *Industrial Health*, **45(1)**, 107-117.
- Nagai, S., G. Yoshida, and K. Tarutani, 2011:** Change in species composition and distribution of algae in the coastal waters of western Japan. In: *Global Warming Impacts – Case Studies on the Economy, Human Health, and on Urban and Natural Environments* [Casalegno, S. (ed.)]. InTech, Rijeka, Croatia, pp. 209-237.
- Nakaegawa, T., A. Kitoh, and M. Hosaka, 2013:** Discharge of major global rivers in the late 21st century climate projected with the high horizontal resolution MRI-AGCMs. *Hydrological Processes*, **27(23)**, 3301-3318.
- Narama, C., A. Kaab, M. Duishonakunov, and K. Abdrakhmatov, 2010:** Spatial variability of recent glacier area changes in the Tien Shan Mountains, Central Asia, using Corona (similar to 1970), Landsat (similar to 2000), and ALOS (similar to 2007) satellite data. *Global and Planetary Change*, **71(1-2)**, 42-54.
- Neo, L., 2012:** Governance issues in climate change adaptation in the Lower Mekong Basin: perspectives from practitioners. *Asian Journal of Environment and Disaster Risk Management*, **4(4)**, 397-424.
- Ngoundo, M., C.E. Kan, Y.C. Chang, S.L. Tsai, and I. Tsou, 2007:** Options for water saving in tropical humid and semi-arid regions using optimum compost application rates. *Irrigation and Drainage*, **56(1)**, 87-98.
- Nguyen, H.N., 2007:** *Flooding in Mekong River Delta, Viet Nam*. Human Development Office Occasional Paper, Human Development Report 2007/2008, United Nations Development Programme (UNDP), New York, NY, USA, 23 pp.
- Nguyen, K.D.T., S.A. Morley, C.-H. Lai, M.S. Clark, K.S. Tan, A.E. Bates, and L.S. Peck, 2011:** Upper temperature limits of tropical marine ectotherms: global warming implications. *PLoS ONE*, **6(12)**, e29340, doi:10.1371/journal.pone.0029340.
- Ni, J.A., 2011:** Impacts of climate change on Chinese ecosystems: key vulnerable regions and potential thresholds. *Regional Environmental Change*, **11(1 Suppl.)**, S49-S64.
- Nicholls, R.J., S. Hanson, C. Herweijer, N. Patmore, S. Hallegatte, J. Corfee-Morlot, J. Chateau, and R. Muir-Wood, 2008:** *Ranking Port Cities with High Exposure and Vulnerability to Climate Extremes: Exposure Estimates*. OECD Environment Working Papers No. 1, Organization for Economic Co-operation and Development (OECD) Publishing, Paris, France, 62 pp.
- Niino, Y., 2011:** Options on land management and land use for coping with climate change in South Asia. In: *Climate Change and Food Security in South Asia* [Lal, R., M.V.K. Sivakumar, S.M.A. Faiz, A.H.M.M. Rahman, and K.R. Islam (eds.)]. Springer Science, Dordrecht, Netherlands, pp. 277-294.
- Niu, D., D. Jiang, and F. Li, 2010:** Higher education for sustainable development in China. *International Journal of Sustainability in Higher Education*, **11(2)**, 153-162.
- Nomura, K. and O. Abe, 2010:** Higher education for sustainable development in Japan: policy and progress. *International Journal of Sustainability in Higher Education*, **11(2)**, 120-129.
- Noordwijk, M., 2010:** Climate change, biodiversity, livelihoods, and sustainability in Southeast Asia. In: *Moving Forward: Southeast Asia Perspectives on Climate Change and Biodiversity* [Sajise, P.E., M.V. Ticsay, and G.C. Saguigut (eds.)]. Institute of Southeast Asian Studies (ISEAS), Pasir Panjang, Singapore and Southeast Asian Regional Center for Graduate Study and Research in Agriculture (SEARCA), Los Baños, Philippines, pp. 55-86.
- Norozi, J., H. Pauli, G. Grabherr, and S.-W. Breckle, 2011:** The subnival-nival vascular plant species of Iran: a unique high-mountain flora and its threat from climate warming. *Biodiversity and Conservation*, **20(6)**, 1319-1338.
- Nuorteva, P., M. Keskinen, and O. Varis, 2010:** Water, livelihoods and climate change adaptation in the Tonle Sap Lake area, Cambodia: learning from the past to understand the future. *Journal of Water and Climate Change*, **1(1)**, 87-101.
- Ogawa-Onishi, Y. and P.M. Berry, 2013:** Ecological impacts of climate change in Japan: the importance of integrating local and international publications. *Biological Conservation*, **157**, 361-371.
- Ohta, S. and A. Kimura, 2007:** Impacts of climate changes on the temperature of paddy waters and suitable land for rice cultivation in Japan. *Agricultural and Forest Meteorology*, **147(3-4)**, 186-198.
- Okunishi, T., S.-i. Ito, T. Hashioka, T.T. Sakamoto, N. Yoshie, H. Sumata, Y. Yara, N. Okada, and Y. Yamanaka, 2012:** Impacts of climate change on growth, migration and recruitment success of Japanese sardine (*Sardinops melanostictus*) in the western North Pacific. *Climatic Change*, **115(3-4)**, 485-503.
- Olden, J.D., M.J. Kennard, J.J. Lawler, and N.L. Poff, 2010:** Challenges and opportunities in implementing managed relocation for conservation of freshwater species. *Conservation Biology*, **25(1)**, 40-47.
- Onozuka, D., M. Hashizume, and A. Hagihara, 2010:** Effects of weather variability on infectious gastroenteritis. *Epidemiology and Infection*, **138(2)**, 236-243.
- Orr, S., J. Pittock, A. Chapagain, and D. Dumaresq, 2012:** Dams on the Mekong River: lost fish protein and the implications for land and water resources. *Global Environmental Change*, **22(4)**, 925-932.
- Ortiz, R., K.D. Sayre, B. Govaerts, R. Gupta, G.V. Subbarao, T. Ban, D. Hodson, J.M. Dixon, J. Iván Ortiz-Monasterio, and M. Reynolds, 2008:** Climate change: can wheat beat the heat? *Agriculture, Ecosystems & Environment*, **126(1-2)**, 46-58.
- Osawa, A., Y. Matsuura, and T. Kajimoto, 2010:** Characteristics of permafrost forests in Siberia and potential responses to warming climate. In: *Permafrost Ecosystems: Siberian Larch Forests* [Osawa, A., O.A. Zyryanova, Y. Matsuura, T. Kajimoto, and R.W. Wein (eds.)]. Springer, Berlin, Germany, pp. 459-481.
- Paaijmans, K.P., S. Blanford, B.H. Chan, and M.B. Thomas, 2012:** Warmer temperatures reduce the vectorial capacity of malaria mosquitoes. *Biology Letters*, **8(3)**, 465-468.
- Page, S.E., J.O. Rieley, and C.J. Banks, 2011:** Global and regional importance of the tropical peatland carbon pool. *Global Change Biology*, **17(2)**, 798-818.
- Pal, I. and A. Al-Tabbaa, 2009:** Trends in seasonal precipitation extremes – an indicator of ‘climate change’ in Kerala, India. *Journal of Hydrology*, **367(1-2)**, 62-69.
- Panday, P.K. and B. Ghimire, 2012:** Time-series analysis of NDVI from AVHRR data over the Hindu Kush-Himalayan region for the period 1982-2006. *International Journal of Remote Sensing*, **33(21)**, 6710-6721.
- Panyakul, V.R., 2012:** Climate change adaptation through agro-social enterprise: green nets experiences in Thailand. *Asian Journal of Environment and Disaster Management*, **4(4)**, 511-526.
- Park, J.H., L. Duan, B. Kim, M.J. Mitchell, and H. Shibata, 2010:** Potential effects of climate change and variability on watershed biogeochemical processes and water quality in Northeast Asia. *Environment International*, **36(2)**, 212-225.
- Partridge, J., P. Ghimire, T. Sedai, M.B. Bista, and M. Banerjee, 2007:** Endemic Japanese encephalitis in the Kathmandu valley, Nepal. *American Journal of Tropical Medicine and Hygiene*, **77(6)**, 1146-1149.
- Pascual, M., X. Rodó, S.P. Ellner, R. Colwell, and M.J. Bouma, 2000:** Cholera dynamics and El Niño-Southern Oscillation. *Science*, **289(5485)**, 1766-1769.
- Patnaik, U. and K. Narayanan, 2009:** *Vulnerability and Climate Change: An Analysis of the Eastern Coastal Districts of India*. MPRA Paper No. 22062, Munich Personal RePEc Archive, Munich University, Munich, Germany, 19 pp.
- Paul, H., A. Ernsting, S. Semino, S. Gura, and A. Lorch, 2009:** *Agriculture and Climate Change: Real Problems, False Solutions*. Report prepared for the Conference of the Parties, COP15, of the United Nations Framework Convention on Climate Change in Copenhagen, December 2009 by Econexus, Biofuelwatch, Grupo de Reflexion Rural, NOAA – Friends of the Earth Denmark, and The Development Fund Norway, EcoNexus, Oxford, UK, 42 pp.
- Paul, S.K. and J.K. Routray, 2010:** Flood-proneness and coping strategies: the experiences of two villages in Bangladesh. *Disasters*, **34(2)**, 489-508.
- Pavlidis, Y.A., S.L. Nikiforov, S.A. Ogorodov, and G.A. Tarasov, 2007:** The Pechora Sea: past, recent, and future. *Oceanology*, **47(6)**, 865-876.
- Pawar, A., R. Bansal, M. Kumar, N. Jain, and K. Vaishnav, 2008:** A rapid assessment of mosquito breeding, vector control measures and treatment seeking behaviour in selected slums of Surat, Gujarat, India, during post-flood period. *Journal of Vector Borne Diseases*, **45(4)**, 325-327.
- Paz, S., N. Bisharat, E. Paz, O. Kidar, and D. Cohen, 2007:** Climate change and the emergence of *Vibrio vulnificus* disease in Israel. *Environmental Research*, **103(3)**, 390-396.
- Pearson, R.G., S.J. Phillips, M.M. Loranty, P.S.A. Beck, T. Damoulas, S.J. Knight, and S.J. Goetz, 2013:** Shifts in Arctic vegetation and associated feedbacks under climate change. *Nature Climate Change*, **3(7)**, 673-677.

- Peh, K.S.H., M.C.K. Soh, N.S. Sodhi, W.F. Laurance, D.J. Ong, and R. Clements, 2011:** Up in the clouds: is sustainable use of tropical montane cloud forests possible in Malaysia? *BioScience*, **61(1)**, 27-38.
- Peng, S., A. Chen, L. Xu, C. Cao, J. Fang, R.B. Myneni, J.E. Pinzon, C.J. Tucker, and S. Piao, 2011:** Recent change of vegetation growth trend in China. *Environmental Research Letters*, **6(4)**, 044027, doi:10.1088/1748-9326/6/4/044027.
- Penning-Rowsell, E., P. Sultana, and P. Thompson, 2011:** *Migration and Global Environmental Change: CS4: Population Movement in Response to Climate-Related Hazards in Bangladesh: The 'Last Resort'*. The Foresight Project, 'Migration and global environmental change' 1st year review, Government Office for Science, London, UK, 38 pp.
- Peras, R.J.J., J.M. Pulhin, R.D. Lasco, R.V.O. Cruz, and F.B. Pulhin, 2008:** Climate variability and extremes in the Pantabangan-Carranglan Watershed, Philippines: assessment of impacts and adaptation practices. *Journal of Environmental Science and Management*, **11(2)**, 14-31.
- Persha, L., H. Fischer, A. Chhatre, A. Agrawal, and C. Benson, 2010:** Biodiversity conversion and livelihoods in human-dominated landscapes: forest commons in South Asia. *Biological Conservation*, **143**, 2918-2925.
- Pfister, S., A. Koehler, and S. Hellweg, 2009:** Assessing the environmental impacts of freshwater consumption in LCA. *Environmental Science & Technology*, **43(11)**, 4098-4104.
- Piguat, E., 2008:** *Climate Change and Forced Migration*. Research Paper No. 153, United Nations High Commissioner for Refugees, Geneva, Switzerland, 15 pp.
- Post, E., U.S. Bhatt, C.M. Bitz, J.F. Brodie, T.L. Fulton, M. Hebblewhite, J. Kerby, S.J. Kutz, I. Stirling, and D.A. Walker, 2013:** Ecological consequences of sea-ice decline. *Science*, **341(6145)**, 519-524.
- Poulter, B., N. Pederson, H. Liu, Z. Zhu, R. D'Arrigo, P. Ciais, N. Davi, D. Frank, C. Leland, R. Myneni, S. Piao, and T. Wang, 2013:** Recent trends in inner Asian forest dynamics to temperature and precipitation indicate high sensitivity to climate change. *Agricultural and Forest Meteorology*, **178(15)**, 31-45.
- Prabhakar, S.V.R.K. and A. Srinivasan, 2011:** Metrics for mainstreaming adaptation in agriculture sector. In: *Climate Change and Food Security in South Asia* [Lal, R., M.V.K. Sivakumar, S.M.A. Faiz, A.H.M.M. Rahman, and K.R. Islam (eds.)]. Springer Science, Dordrecht, Netherlands, pp. 551-568.
- Prabhakar, S.V.R.K., T. Kobashi, and A. Srinivasan, 2010:** Monitoring progress of adaptation to climate change: the use of adaptation metrics. *Asian Journal of Environment and Disaster Management* **2(3)**, 435-442.
- PRB, 2012:** *2012 World Population Data Sheet*. Population Reference Bureau (PRB), Washington, DC, USA, 20 pp.
- Prentice, M.L. and S. Glidden, 2010:** Glacier crippling and the rise of the snowline in western New Guinea (Papua Province, Indonesia) from 1972 to 2000. In: *Altered Ecologies: Fire, Climate and Human Influence on Terrestrial Landscapes* [Haberle, S.G., J. Stevenson, and M. Prebble (eds.)]. Australian National University (ANU) Press, Canberra, ACT, Australia, pp. 457-471.
- Putz, F.E., P.A. Zuidema, T. Synnott, M. Peña-Claros, M.A. Pinard, D. Sheil, J.K. Vanclay, P. Sist, S. Gourlet-Fleury, B. Griscom, J. Palmer, and R. Zagt, 2012:** Sustaining conservation values in selectively logged tropical forests: the attained and the attainable. *Conservation Letters*, **5(4)**, 296-303.
- Qian, Y., S. Li, Q. Wang, K. Yang, G. Yang, S. Lü, and X. Zhou, 2010:** Advances on impact of climate change on human health. *Advances in Climate Change Research*, **6(4)**, 241-247.
- Qin, Z., Q. Zhuang, X. Zhu, X. Cai, and X. Zhang, 2011:** Carbon consequences and agricultural implications of growing biofuel crops on marginal agricultural lands in China. *Environmental Science & Technology*, **45(24)**, 10765-10772.
- Qiu, Y.S., Z.J. Lin, and Y.Z. Wang, 2010:** Responses of fish production to fishing and climate variability in the northern South China Sea. *Progress in Oceanography*, **85(3-4)**, 197-212.
- Räsänen, T.A., J. Koponen, H. Lauri, and M. Kummu, 2012:** Downstream hydrological impacts of hydropower development in the Upper Mekong Basin. *Water Resources Management*, **26(12)**, 3495-3513.
- Radić, V., A. Bliss, A.C. Beedlow, R. Hock, E. Miles, and J.G. Cogley, 2013:** Regional and global projections of twenty-first century glacier mass changes in response to climate scenarios from global climate models. *Climate Dynamics* (in press), doi:10.1007/s00382-013-1719-7.
- Ranger, N., S. Hallegatte, S. Bhattacharya, M. Bachu, S. Priya, K. Dhore, F. Rafique, P. Mathur, N. Naville, F. Henriot, C. Herweijer, S. Pohit, and J. Corfee-Morlot, 2011:** An assessment of the potential impact of climate change on flood risk in Mumbai. *Climatic Change*, **104(1)**, 139-167.
- Ratnakumar, P., V. Vadez, L. Krishnamurthy, and G. Rajendrudu, 2011:** Semi-arid crop responses to atmospheric elevated CO₂. *Plant Stress*, **5(1)**, 42-51.
- Ravallion, M., S. Chen, and P. Sangraula, 2007:** *New Evidence on the Urbanization of Global Poverty*. Background Paper for the World Development Report 2008, Policy Research Working Paper 4199, The World Bank, Washington, DC, USA, 46 pp.
- Razumov, S.O., 2010:** Permafrost as a factor of the dynamics of the coastal zone of the Russian East Arctic Seas. *Oceanology*, **50(2)**, 262-267.
- Ren, W., H. Tian, B. Tao, A. Chappelka, G. Sun, C. Lu, M. Liu, G. Chen, and X. Xu, 2011:** Impacts of tropospheric ozone and climate change on net primary productivity and net carbon exchange of China's forest ecosystems. *Global Ecology and Biogeography*, **20(3)**, 391-406.
- Revi, A., 2008:** Climate change risk: an adaptation and mitigation agenda for Indian cities. *Environment and Urbanization*, **20(1)**, 207-229.
- Reynolds, C.C.O. and M. Kandikar, 2008:** Climate impacts of air quality policy: switching to a natural gas-fueled public transportation system in New Delhi. *Environmental Science & Technology*, **42(16)**, 5860-5865.
- Richardson, A.D., T.F. Keenan, M. Migliavacca, Y. Ryu, O. Sonnentag, and M. Toomey, 2013:** Climate change, phenology, and phenological control of vegetation feedbacks to the climate system. *Agricultural and Forest Meteorology*, **169**, 156-173.
- Riseborough, D., N. Shiklomanov, B. Eitzelmüller, S. Gruber, and S. Marchenko, 2008:** Recent advances in permafrost modelling. *Permafrost and Periglacial Processes*, **19(2)**, 137-156.
- Rodó, X., M. Pascual, G. Fuchs, and A. Faruque, 2002:** ENSO and cholera: a nonstationary link related to climate change? *Proceedings of the National Academy of Sciences of the United States of America*, **99(20)**, 12901-12906.
- Rodell, M., I. Velicogna, and J.S. Famiglietti, 2009:** Satellite-based estimates of groundwater depletion in India. *Nature*, **460(7258)**, 999-1002.
- Romanovsky, V.E., A.L. Kholodov, S.S. Marchenko, N.G. Oberman, D.S. Drozdov, G.V. Malkova, N.G. Moskalenko, A.A. Vasiliev, D.O. Sergeev, and M.N. Zheleznyak, 2008:** Thermal state and fate of permafrost in Russia: first results of IPY. In: *Ninth International Conference on Permafrost, Vol. 1* [Kane, D.L. and K.M. Hinkel (eds.)]. Proceedings of the Ninth International Conference on Permafrost, June 29 - July 3, 2008, Institute of Northern Engineering, University of Alaska, Fairbanks, AK, USA, pp. 1511-1518.
- Romanovsky, V.E., D.S. Drozdov, N.G. Oberman, G.V. Malkova, A.L. Kholodov, S.S. Marchenko, N.G. Moskalenko, D.O. Sergeev, N.G. Ukraintseva, A.A. Abramov, D.A. Gilichinsky, and A.A. Vasiliev, 2010:** Thermal state of permafrost in Russia. *Permafrost and Periglacial Processes*, **21(2)**, 136-155.
- Romero Lankao, P. and D.M. Gnatz, 2011:** Conclusions and policy directions. In: *Cities and Climate Change, Global Report on Human Settlements 2011* [Mutizwa-Mangiza, N.D. (ed.)]. United Nations Human Settlements Programme (UN-HABITAT), Earthscan, London, UK and Washington, DC, USA, pp. 163-183.
- Rosegrant, M.W., 2011:** Impacts of climate change on food security and livelihoods. In: *Food Security and Climate Change in Dry Areas: Proceedings of an International Conference, 1-4 February 2010, Amman, Jordan* [Solh, M. and M.C. Saxena (eds.)]. International Center for Agricultural Research in the Dry Areas (ICARDA), Aleppo, Syria, pp. 24-26.
- Roth, C.H. and C.M. Grunbuhel, 2012:** Developing multi-scale adaptation strategies: a case study for farming communities in Cambodia and Laos. *Asian Journal of Environment and Disaster Risk Management*, **4(4)**, 441-462.
- Ryan, A., D. Tilbury, P.B. Corcoran, O. Abe, and K. Nomura, 2010:** Sustainability in higher education in the Asia-Pacific: developments, challenges and prospects. *International Journal of Sustainability in Higher Education*, **11(2)**, 106-119.
- Sadoff, C. and M. Muller, 2009:** *Water Management, Water Security and Climate Change Adaptation: Early Impacts and Essential Responses*. TEC Background Paper No.14, Global Water Partnership (GWP) Technical Committee (TEC), GWP Secretariat, Stockholm, Sweden, 85 pp.
- Sakai, S., R.D. Harrison, K. Momose, K. Kuraji, H. Nagamasu, T. Yasunari, L. Chong, and T. Nakashizuka, 2006:** Irregular droughts trigger mass flowering in aseasonal tropical forests in Asia. *American Journal of Botany*, **93(8)**, 1134-1139.
- Salick, J. and N. Ross, 2009:** Traditional peoples and climate change. *Global Environmental Change*, **19(2)**, 137-139.
- Salick, J., Z. Fang, and A. Byg, 2009:** Eastern Himalayan alpine plant ecology, Tibetan ethnobotany, and climate change. *Global Environmental Change*, **19(2)**, 147-155.
- Sano, M., F. Furuta, and T. Sweda, 2010:** Summer temperature variations in southern Kamchatka as reconstructed from a 247-year tree-ring chronology of *Betula ermanii*. *Journal of Forest Research*, **15(4)**, 234-240.

- Sasaki, N., G.P. Asner, W. Knorr, P.B. Durst, H.R. Priyadi, and F.E. Putz, 2011: Approaches to classifying and restoring degraded tropical forests for the anticipated REDD+ climate change mitigation mechanism. *iForest-Biogeosciences and Forestry*, **4(1)**, 1-6, doi: 10.3832/ifer0556-004.
- Sato, T., F. Kimura, and A. Kitoh, 2007: Projection of global warming onto regional precipitation over Mongolia using a regional climate model. *Journal of Hydrology*, **333(1)**, 144-154.
- Sato, Y., T. Kojiri, Y. Michihiro, Y. Suzuki, and E. Nakakita, 2012: Estimates of climate change impact on river discharge in Japan based on a super-high-resolution climate model. *Terrestrial Atmospheric and Oceanic Sciences*, **23(5)**, 527-540.
- Sato, Y., T. Kojiri, Y. Michihiro, Y. Suzuki, and E. Nakakita, 2013: Assessment of climate change impacts on river discharge in Japan using the super-high-resolution MRI-AGCM. *Hydrological Processes*, **27(23)**, 3264-3279.
- Schaefer, K., T.J. Zhang, L. Bruhwiler, and A.P. Barrett, 2011: Amount and timing of permafrost carbon release in response to climate warming. *Tellus B*, **63(2)**, 165-180.
- Schaffer, A.S. and L. Ding, 2012: Strengthening climate adaptation in the Lower Mekong River basin through a regional adaptation action network. *Asian Journal of Environment and Disaster Risk Management*, **4(4)**, 543-565.
- Schlüter, M., D. Hirsch, and C. Pahl-Wostl, 2010: Coping with change: responses of the Uzbek water management regime to socio-economic transition and global change. *Environmental Science & Policy*, **13(7)**, 620-636.
- Selvaraju, R., A.R. Subbiah, S. Baas, and I. Juergens, 2006: *Livelihood Adaptation to Climate Variability and Change in Drought-Prone Areas of Bangladesh: Developing Institutions and Options*. The Institutions for Rural Development Series 5, Asian Disaster Preparedness Center, Food and Agriculture Organization of the United Nations (FAO), Rome, Italy, 97 pp.
- Shahgedanova, M., G. Nosenko, T. Khromova, and A. Muraveyev, 2010: Glacier shrinkage and climatic change in the Russian Altai from the mid-20th century: an assessment using remote sensing and PRECIS regional climate model. *Journal of Geophysical Research: Atmospheres*, **115**, D16107, doi:10.1029/2009JD012976.
- Shahgedanova, M., G. Nosenko, I. Bushueva, and M. Ivanov, 2012: Changes in area and geodetic mass balance of small glaciers, Polar Urals, Russia, 1950-2008. *Journal of Glaciology*, **58(211)**, 953-964.
- Shang, C.-S., C.-T. Fang, C.-M. Liu, T.-H. Wen, K.-H. Tsai, and C.-C. King, 2010: The role of imported cases and favorable meteorological conditions in the onset of dengue epidemics. *PLoS Neglected Tropical Diseases*, **4(8)**, e775, doi:10.1371/journal.pntd.0000775.
- Shao, X., Y. Xu, Z.Y. Yin, E. Liang, H. Zhu, and S. Wang, 2010: Climatic implications of a 3585-year tree-ring width chronology from the northeastern Qinghai-Tibetan Plateau. *Quaternary Science Reviews*, **29(17-18)**, 2111-2122.
- Sharkhuu, N., A. Sharkhuu, V.E. Romanovsky, K. Yoshikawa, F.E. Nelson, and N.I. Shiklomanov, 2008: Thermal state of permafrost in Mongolia. In: *Ninth International Conference on Permafrost, Vol. 1* [Kane, D.L., and K.M. Hinkel (eds.)]. Proceedings of the Ninth International Conference on Permafrost, June 29 - July 3, 2008. Institute of Northern Engineering, University of Alaska, Fairbanks, AK, USA, pp.1633-1638.
- Shaw, R., F. Mallick, and Y. Takeuchi, 2011: Essentials of higher education in disaster risk reduction: prospects and challenges. In: *Disaster Education, Community, Environment and Disaster Risk Management, Vol. 7* [Shaw, R., K. Shiwaku, and Y. Takeuchi (eds.)]. Emerald Group Publishing, Ltd., Bingley, UK, pp. 95-113.
- Shen, M., Z. Sun, S. Wang, G. Zhang, W. Kong, A. Chen, and S. Piao, 2013: No evidence of continuously advanced green-up dates in the Tibetan Plateau over the last decade. *Proceedings of the National Academy of Sciences of the United States of America*, **110(26)**, E2329, doi:10.1073/pnas.1304625110.
- Shishov, V.V. and E.A. Vaganov, 2010: Dendroclimatological evidence of climate changes across Siberia. In: *Environmental Change in Siberia: Earth Observation, Field Studies and Modelling* [Balzter, H. (ed.)]. Springer, Dordrecht, Netherlands, pp. 101-114.
- Shoo, L.P., C. Storlie, J. Vanderwal, J. Little, and S.E. Williams, 2011: Targeted protection and restoration to conserve tropical biodiversity in a warming world. *Global Change Biology*, **17(1)**, 186-193.
- Shrestha, A.B. and R. Aryal, 2011: Climate change in Nepal and its impact on Himalayan glaciers. *Regional Environmental Change*, **11(Suppl. 1)**, S65-S77.
- Shrestha, U.B., S. Gautam, and K.S. Bawa, 2012: Widespread climate change in the Himalayas and associated changes in local ecosystems. *PLoS ONE*, **7(5)**, e36741, doi:10.1371/journal.pone.0036741.
- Shuang-He, S., S.-B. Yang, Y.-X. Zhao, Y.-L. Xu, X.-Y. Zhao, Z.-Y. Wang, J. Liu, and W.-W. Zhang, 2011: Simulating the rice yield change in the middle and lower reaches of the Yangtze River under SRES B2 scenario. *Acta Ecologica Sinica*, **31(1)**, 40-48.
- Siegfried, T., T. Bernauer, R. Guennet, S. Sellars, A.W. Robertson, J. Mankin, and P. Bauer-Gottwein, 2010: *Coping with International Water Conflict in Central Asia: Implications of Climate Change and Melting Ice in the Syr Darya Catchment*. International Peace Research Institute, Oslo, Norway, 36 pp.
- Singh, C.P., S. Panigrahy, A. Thapliyal, M.M. Kimothi, P. Soni, and J.S. Parihar, 2012: Monitoring the alpine treeline shift in parts of the Indian Himalayas using remote sensing. *Current Science*, **102(4)**, 559-562.
- Sitch, S., C. Huntingford, N. Gedney, P.E. Levy, M. Lomas, S.L. Piao, R. Betts, P. Ciais, P. Cox, P. Friedlingstein, C.D. Jones, I.C. Prentice, and F.I. Woodward, 2008: Evaluation of the terrestrial carbon cycle, future plant geography and climate-carbon cycle feedbacks using five Dynamic Global Vegetation Models (DGVMs). *Global Change Biology*, **14(9)**, 2015-2039.
- Sivakumar, M.V. and R. Stefanski, 2011: Climate change in South Asia. In: *Climate Change and Food Security in South Asia* [Lal, R., M.V.K. Sivakumar, S.M.A. Faiz, A.H.M.M. Rahman, and K.R. Islam (eds.)]. Springer, Dordrecht, Netherlands, pp. 13-30.
- Skoufias, E., M. Rabassa, and S. Olivieri, 2011: *The Poverty Impacts of Climate Change: A Review of the Evidence*. Policy Research Working Paper 5622, Poverty Reduction and Equity Unit, Poverty Reduction and Economic Management Network, The World Bank, Washington, DC, USA, 35 pp.
- Smith, L.C. and S.R. Stephenson, 2013: New trans-Arctic shipping routes navigable by midcentury. *Proceedings of the National Academy of Sciences of the United States of America*, **110(13)**, E1191-E1195.
- Sodhi, N.S., M.R.C. Posa, T.M. Lee, D. Bickford, L.P. Koh, and B.W. Brook, 2010: The state and conservation of Southeast Asian biodiversity. *Biodiversity and Conservation*, **19(2)**, 317-328.
- Sohan, L., B. Shyamal, T.S. Kumar, M. Malini, K. Ravi, V. Venkatesh, M. Veena, and S. Lal, 2008: Studies on leptospirosis outbreaks in Peddamandem Mandal of Chittoor district, Andhra Pradesh. *Journal of Communicable Diseases*, **40(2)**, 127-132.
- Soja, A.J., N.M. Tchebakova, N.H.F. French, M.D. Flannigan, H.H. Shugart, B.J. Stocks, A.I. Sukhinin, E.I. Parfenova, F.S. Chapin, and P.W. Stackhouse, 2007: Climate-induced boreal forest change: predictions versus current observations. *Global and Planetary Change*, **56(3-4)**, 274-296.
- Solberg, K., 2010: Worst floods in living memory leave Pakistan in paralysis. *The Lancet*, **376(9746)**, 1039-1040.
- Sorg, A., T. Bolch, M. Stoffel, O. Solomina, and M. Beniston, 2012: Climate change impacts on glaciers and runoff in Tien Shan (Central Asia). *Nature Climate Change*, **2(10)**, 725-731.
- Spalding, M., C. Ravilious, and E.P. Green, 2001: *World Atlas of Coral Reefs*. University of California Press, Berkeley, CA, USA, 424 pp.
- Spotila, J.R., 2004: *Sea Turtles: A Complete Guide to Their Biology, Behavior, and Conservation*. Johns Hopkins University Press, Baltimore, MD, USA, 227 pp.
- Sriprom, M., K. Chalvet-Monfray, T. Chaimane, K. Vongsawat, and D. Bicout, 2010: Monthly district level risk of dengue occurrences in Sakon Nakhon Province, Thailand. *Science of the Total Environment*, **408(22)**, 5521-5528.
- Srivastava, A., S. Naresh Kumar, and P.K. Aggarwal, 2010: Assessment on vulnerability of sorghum to climate change in India. *Agriculture, Ecosystems and Environment*, **138(3-4)**, 160-169.
- Stage, J., 2010: Economic valuation of climate change adaptation in developing countries. *Annals of the New York Academy of Sciences*, **1185**, 150-163.
- Stewart, M.G., X.M. Wang, and M.N. Nguyen, 2012: Climate change adaptation for corrosion control of concrete infrastructure. *Structural Safety*, **35**, 29-39.
- Stokes, C.R., M. Shahgedanova, I.S. Evans, and V.V. Popovnin, 2013: Accelerated loss of alpine glaciers in the Kodar Mountains, south-eastern Siberia. *Global and Planetary Change*, **101**, 82-96.
- Storch, H. and N.K. Downes, 2011: A scenario-based approach to assess Ho Chi Minh City's urban development strategies against the impact of climate change. *Cities*, **28(6)**, 517-526.
- Stucki, V. and M. Smith, 2011: Integrated approaches to natural resources management in practice: the catalyzing role of National Adaptation Programmes for Action. *AMBIO: A Journal of the Human Environment*, **40(4)**, 351-360.
- Su, G.L.S., 2008: Correlation of climatic factors and dengue incidence in Metro Manila, Philippines. *AMBIO: A Journal of the Human Environment*, **37(4)**, 292-294.
- Su, Y., Y. Weng, and Y. Chiu, 2009: Climate change and food security in East Asia. *Asia Pacific Journal of Clinical Nutrition*, **18(4)**, 674-678.

- Sugiura, T., H. Sumida, S. Yokoyama, and H. Ono, 2012: Overview of recent effects of global warming on agricultural production in Japan. *Japan Agricultural Research Quarterly*, **46**(1), 7-13.
- Sumaila, U.R., W.W.L. Cheung, V.W.Y. Lam, D. Pauly, and S. Herrick, 2011: Climate change impacts on the biophysics and economics of world fisheries. *Nature Climate Change*, **1**(9), 449-456.
- Sun, P., Z. Yu, S. Liu, X. Wei, J. Wang, N. Zegre, and N. Liu, 2012: Climate change, growing season water deficit and vegetation activity along the north-south transect of Eastern China from 1982 through 2006. *Hydrology and Earth System Sciences*, **16**(10), 3835-3850.
- Surazakov, A.B., V.B. Aizen, E.M. Aizen, and S.A. Nikitin, 2007: Glacier changes in the Siberian Altai Mountains, Ob river basin, (1952-2006) estimated with high resolution imagery. *Environmental Research Letters*, **2**, 045017, doi:10.1088/1748-9326/2/4/045017.
- Sutton, W.R., J.P. Srivastava, and J.E. Neumann, 2013: *Looking Beyond the Horizon: How Climate Change Impacts and Adaptation Responses Will Reshape Agriculture in Eastern Europe and Central Asia*. Directions in Development: Agriculture and Rural Development, International Bank for Reconstruction and Development/The World Bank, Washington, DC, USA, 177 pp.
- Syvitski, J.P.M., A.J. Kettner, I. Overeem, E.W.H. Hutton, M.T. Hannon, G.R. Brakenridge, J. Day, C. Vörösmarty, Y. Saito, L. Giosan, and R.J. Nicholls, 2009: Sinking deltas due to human activities. *Nature Geoscience*, **2**(10), 681-686.
- Tan, J., Y. Zheng, G. Song, L.S. Kalkstein, A.J. Kalkstein, and X. Tang, 2007: Heat wave impacts on mortality in Shanghai, 1998 and 2003. *International Journal of Biometeorology*, **51**(3), 193-200.
- Tan, J., Y. Zheng, X. Tang, C. Guo, L. Li, G. Song, X. Zhen, D. Yuan, A.J. Kalkstein, and F. Li, 2010: The urban heat island and its impact on heat waves and human health in Shanghai. *International Journal of Biometeorology*, **54**(1), 75-84.
- Tan, Z.-H., M. Cao, G.-R. Yu, J.-W. Tang, X.-B. Deng, Q.-H. Song, Y. Tang, Z. Zheng, W.-J. Liu, Z.-L. Feng, Y. Deng, J.-L. Zhang, N. Liang, and Y.-P. Zhang, 2013: High sensitivity of a tropical rainforest to water variability: evidence from 10 years of inventory and eddy flux data. *Journal of Geophysical Research: Atmospheres*, **118**(16), 9393-9400.
- Tanaka, K., S. Taino, H. Haraguchi, G. Prendergast, and M. Hiraoka, 2012: Warming off southwestern Japan linked to distributional shifts of subtidal canopy-forming seaweeds. *Ecology and Evolution*, **2**(11), 2854-2865.
- Tanaka, N., K. Nakao, I. Tsuyama, M. Higa, E. Nakazono, and T. Matsui, 2012: Predicting the impact of climate change on potential habitats of fir (*Abies*) species in Japan and on the East Asian continent. *Procedia Environmental Sciences*, **13**, 455-466.
- Tao, F. and Z. Zhang, 2010: Adaptation of maize production to climate change in North China Plain: quantify the relative contributions of adaptation options. *European Journal of Agronomy*, **33**, 103-116.
- Tao, F. and Z. Zhang, 2013a: Climate change, high-temperature stress, rice productivity, and water use in Eastern China: a new superensemble-based probabilistic projection. *Journal of Applied Meteorology and Climatology*, **52**(3), 531-551.
- Tao, F. and Z. Zhang, 2013b: Climate change, wheat productivity and water use in the North China Plain: a new super-ensemble-based probabilistic projection. *Agricultural and Forest Meteorology*, **170**(15), 146-165.
- Tao, F., Z. Zhang, J. Liu, and M. Yokozawa, 2009: Modelling the impacts of weather and climate variability on crop productivity over a large area: a new super-ensemble-based probabilistic projection. *Agricultural and Forest Meteorology*, **149**(8), 1266-1278.
- Taylor, J., 2011: Community-based vulnerability assessment: Semarang, Indonesia. In: *Resilient Cities: Cities and Adaptation to Climate Change – Proceedings of the Global Forum 2010* [Otto Zimmermann, K. (ed.)]. Local Sustainability Series, Vol.1, Springer, Dordrecht, Netherlands, pp. 329-337.
- Tchebakova, N.M., G.E. Rehfeldt, and E.I. Parfenova, 2010: From vegetation zones to climatotypes: effects of climate warming on Siberian ecosystems. In: *Permafrost Ecosystems: Siberian Larch Forests* [Osawa, A., O.A. Zyryanova, Y. Matsuura, T. Kajimoto, and R.W. Wein (eds.)]. Springer, Berlin, Germany, pp. 427-446.
- Tchebakova, N.M., E.I. Parfenova, and A.J. Soja, 2011: Climate change and climate-induced hot spots in forest shifts in central Siberia from observed data. *Regional Environmental Change*, **11**(4), 817-827.
- Telles, S., N. Singh, and M. Joshi, 2009: Risk of posttraumatic stress disorder and depression in survivors of the floods in Bihar, India. *Indian Journal of Medical Sciences*, **63**(8), 330-334.
- Telwala, Y., B.W. Brook, K. Manish, and M.K. Pandit, 2013: Climate-induced elevational range shifts and increase in plant species richness in a Himalayan biodiversity epicentre. *PLoS One*, **8**(2), e57103, doi:10.1371/journal.pone.0057103.
- Terazono, Y., Y. Nakamura, Z. Imoto, and M. Hiraoka, 2012: Fish response to expanding tropical *Sargassum* beds on the temperate coasts of Japan. *Marine Ecology Progress Series*, **464**, 209-220.
- Thomas, R.J., 2008: Opportunities to reduce the vulnerability of dryland farmers in Central and West Asia and North Africa to climate change. *Agriculture, Ecosystems & Environment*, **126**(1-2), 36-45.
- Thomson, A.M., R.C. Izaurralde, N.J. Rosenberg, and X. He, 2006: Climate change impacts on agriculture and soil carbon sequestration potential in the Huang-Hai Plain of China. *Agriculture, Ecosystems & Environment*, **114**(2-4), 195-209.
- Thomson, A.M., K.V. Calvin, L.P. Chini, G. Hurtt, J.A. Edmonds, B. Bond-Lamberty, S. Frolking, M.A. Wise, and A.C. Janetos, 2010: Climate mitigation and the future of tropical landscapes. *Proceedings of the National Academy of Sciences of the United States of America*, **107**, 19633-19638.
- Tian, X., T. Matsui, S. Li, M. Yoshimoto, K. Kobayasi, and T. Hasegawa, 2010: Heat-induced floret sterility of hybrid rice (*Oryza sativa* L.) cultivars under humid and low wind conditions in the field of Jiangnan Basin, China. *Plant Production Science*, **13**(3), 243-251.
- Tian, Y., H. Kidokoro, T. Watanabe, Y. Igeta, H. Sakaji, and S. Ino, 2012: Response of yellowtail, *Seriola quinqueradiata*, a key large predatory fish in the Japan Sea, to sea water temperature over the last century and potential effects of global warming. *Journal of Marine Systems*, **91**(1), 1-10.
- Tirado, M., R. Clarke, L. Jaykus, A. McQuatters-Gollop, and J. Frank, 2010: Climate change and food safety: a review. *Food Research International*, **43**(7), 1745-1765.
- Tischbein, B., A.M. Manschadi, A.K. Hornidge, C. Conrad, J.P.A. Lamers, L. Oberkircher, G. Schorcht, and P.L.G. Vlek, 2011: Proposals for the more efficient utilization of water resources in the Province of Khorezm, Uzbekistan. *Hydrologie und Wasserbewirtschaftung*, **55**(2), 116-125.
- Tobey, J., P. Rubinoff, D. Robadue Jr., G. Ricci, R. Volk, J. Furlow, and G. Anderson, 2010: Practicing coastal adaptation to climate change: lessons from integrated coastal management. *Coastal Management*, **38**(3), 317-335.
- Tosca, M.G., J.T. Randerson, and C.S. Zender, 2012: Global impact of contemporary smoke aerosols from landscape fires on climate and the Hadley circulation. *Atmospheric Chemistry and Physics Discussions*, **12**, 28069-28108.
- Tougou, D., D.L. Musolin, and K. Fujisaki, 2009: Some like it hot! Rapid climate change promotes changes in distribution ranges of *Nezara viridula* and *Nezara antennata* in Japan. *Entomologia Experimentalis et Applicata*, **130**(3), 249-258.
- Tseng, C.-T., C.-L. Sun, S.-Z. Yeh, S.-C. Chen, W.-C. Su, and D.-C. Liu, 2011: Influence of climate-driven sea surface temperature increase on potential habitats of the Pacific saury (*Cololabis saira*). *ICES Journal of Marine Science*, **68**(6), 1105-1113.
- Tuanmu, M.-N., A. Vina, J.A. Winkler, Y. Li, W. Xu, Z. Ouyang, and J. Liu, 2012: Climate-change impacts on understorey bamboo species and giant pandas in China's Qinling Mountains. *Nature Climate Change*, **3**, 249-253.
- Tyler, S. and M. Moench, 2012: A framework for urban climate resilience. *Climate and Development*, **4**(4), 311-326.
- Udomratn, P., 2008: Mental health and the psychosocial consequences of natural disasters in Asia. *International Review of Psychiatry*, **20**(5), 441-444.
- UN DESA Population Division, 2012: *World Urbanization Prospects: The 2011 Revision*. ESA/P/WP/224, United Nations Department of Economic and Social Affairs (UN DESA) Population Division, New York, NY, USA, 302 pp.
- UN DESA Population Division, 2013: *World Population Prospects: The 2012 Revision, Volume I: Comprehensive Tables*. ST/ESA/SER.A/336, United Nations Department of Economic and Social Affairs (UN DESA) Population Division, New York, NY, USA, 439 pp.
- UN DESA Statistics Division, 2009: *The Millennium Development Goals Report 2009*. Produced and published by the United Nations Department of Economic and Social Affairs (UN DESA) Statistics Division, New York, NY, USA, 56 pp.
- UN ESCAP, 2011: *Statistical Yearbook for Asia and the Pacific 2011*. United Nations Economic and Social Commission for Asia and the Pacific (UN ESCAP) Statistics Division, Bangkok, Thailand, 286 pp.
- UN ESCAP, ADB, and UNEP, 2012: *Green Growth, Resources and Resilience: Environmental Sustainability in Asia and the Pacific*. The United Nations Economic and Social Commission for Asia and the Pacific (UN ESCAP), the Asian Development Bank (ADB), and the United Nations Environment Programme (UNEP), Bangkok, Thailand, 157 pp.
- UNDP, 2006: *Human Development Report 2006. Beyond Scarcity: Power, Poverty and the Global Water Crisis*. United Nations Development Programme (UNDP), Palgrave Macmillan, Houndmills, UK and New York, NY, USA, 422 pp.

- UNEP, 2010: *Blue Harvest: Inland Fisheries as an Ecosystem Service*. Prepared for the United Nations Environment Programme (UNEP) by the WorldFish Center, Penang, Malaysia, 63 pp.
- UNEP, 2012: *Summary for Policy Makers Highlights the Findings of the Fifth Global Environment Outlook (GEO-5) Report*. United Nations Environment Programme (UNEP), Nairobi, Kenya, 20 pp.
- UNESCO, 2012: *The United Nations World Water Development Report 4: Managing Water under Uncertainty and Risk – Volume 1*. United Nations World Water Assessment Programme, United Nations Educational, Scientific and Cultural Organization (UNESCO), Paris, France, 866 pp.
- UNFCCC, 2009: *Potential Costs and Benefits of Adaptation Options: A Review of Existing Literature: Technical Paper*. FCCC/TPI/2009/2/Rev.1, 11 May 2010, United Nation Framework Convention on Climate Change (UNFCCC), Bonn, Germany, 83 pp.
- UN-HABITAT, 2010: *The State of Asian Cities 2010/11*. United Nations Human Settlements Programme (UN-HABITAT) and United Nations Economic and Social Commission for Asia and the Pacific (UN ESCAP), UN-HABITAT-Regional Office for Asia and the Pacific, Fukuoka, Japan, 270 pp.
- UN-HABITAT, 2011: *Cities and Climate Change: Global Report on Human Settlements 2011*. United Nations Human Settlements Programme (UN-HABITAT), Earthscan, London, UK and Washington, DC, USA, 279 pp.
- UNISDR, 2011: *Global Assessment Report on Disaster Risk Reduction 2011. Revealing Risk, Redefining Development*. United Nations International Strategy for Disaster Reduction (UNISDR), Geneva, Switzerland, 178 pp.
- Upreti, K. and S.M.A. Salman, 2011: Legal aspects of sharing and management of transboundary waters in South Asia: preventing conflicts and promoting cooperation. *Hydrological Sciences Journal*, **56**(4), 641-661.
- Uy, N., Y. Takeuchi, and R. Shaw, 2011: Local adaptation for livelihood resilience in Albay, Philippines. *Environmental Hazards*, **10**(2), 139-153.
- van Aalst, M.K., T. Cannon, and I. Burton, 2008: Community level adaptation to climate change: the potential role of participatory community risk assessment. *Global Environmental Change: Human and Policy Dimensions*, **18**(1), 165-179.
- van Hooijdonk, R., J.A. Maynard, and S. Planes, 2013: Temporary refugia for coral reefs in a warming world. *Nature Climate Change*, **3**(5), 508-511.
- Vargas-Silva, C., S. Jha, and G. Sugiyarto, 2009: *Remittances in Asia: Implications for the Fight Against Poverty and the Pursuit of Economic Growth*. ADB Economics Working Paper Series No. 182, Asian Development Bank (ADB), Manila, Philippines, 28 pp.
- Verchot, L.V., M. Noordwijk, S. Kandji, T. Tomich, C. Ong, A. Albrecht, J. Mackensen, C. Bantilan, K.V. Anupama, and C. Palm, 2007: Climate change: linking adaptation and mitigation through agroforestry. *Mitigation and Adaptation Strategies for Global Change*, **12**(5), 901-918.
- Villanoy, C., L. David, O. Cabrera, M. Atrigenio, F. Siringan, P. Aliño, and M. Villaluz, 2012: Coral reef ecosystems protect shore from high-energy waves under climate change scenarios. *Climatic Change*, **112**(2), 493-505.
- Vörösmarty, C.J., P.B. McIntyre, M.O. Gessner, D. Dudgeon, A. Prusevich, P. Green, S. Glidden, S.E. Bunn, C.A. Sullivan, C.R. Liermann, and P.M. Davies, 2010: Global threats to human water security and river biodiversity. *Nature*, **467**(7315), 555-561.
- Waddell, S., 2005: *Societal Learning and Change: How Governments, Business and Civil Society are Creating Solutions to Complex Multi-Stakeholder Problems*. Greenleaf Publishing, Ltd., Sheffield, UK, 164 pp.
- Waddell, S. and S. Khagram, 2007: Multi-stakeholder global networks: emerging systems for the global common good. *Partnerships, Governance and Sustainable Development: Reflections on Theory and Practice* [Glasbergen, P., F. Biermann, and A.P.J. Mol (eds.)]. Edward Elgar Publishing, Ltd., Cheltenham, UK and Northampton, MA, USA, pp. 261-287.
- Wang, G., W. Bai, N. Li, and H. Hu, 2011: Climate changes and its impact on tundra ecosystem in Qinghai-Tibet Plateau, China. *Climatic Change*, **106**(3), 463-482.
- Wang, H., 2013: A multi-model assessment of climate change impacts on the distribution and productivity of ecosystems in China. *Regional Environmental Change* (in press), doi:10.1007/s10113-013-0469-8.
- Wang, X. and H. Liu, 2012: Dynamics change of *Betula ermanii* population related to shrub and grass on treeline of northern slope of Changbai Mountains. *Acta Ecologica Sinica*, **32**(10), 3077-3086.
- Wangdi, K., P. Singhasivanon, T. Silawan, S. Lawpoolsri, N.J. White, and J. Kaewkungwal, 2010: Development of temporal modelling for forecasting and prediction of malaria infections using time-series and ARIMAX analyses: a case study in endemic districts of Bhutan. *Malaria Journal*, **9**, 251, doi:10.1186/1475-2875-9-251.
- Warner, K., 2010: Global environmental change and migration: governance challenges. *Global Environmental Change*, **20**(3), 402-413.
- Warraich, H., A.K. Zaidi, and K. Patel, 2011: Floods in Pakistan: a public health crisis. *Bulletin of the World Health Organization*, **89**(3), 236-237.
- Wassmann, R., S.V.K. Jagadish, S. Heuer, A. Ismail, E. Redona, R. Serraj, R.K. Singh, G. Howell, H. Pathak, and K. Sumfleth, 2009a: Climate change affecting rice production: the physiological and agronomic basis for possible adaptation strategies. In: *Advances in Agronomy, Vol. 101* [Sparks, D.L. (ed.)]. Academic Press, Burlington, MA, USA, pp. 59-122.
- Wassmann, R., S.V.K. Jagadish, K. Sumfleth, H. Pathak, G. Howell, A. Ismail, R. Serraj, E. Redona, R.K. Singh, and S. Heuer, 2009b: Regional vulnerability of climate change impacts on Asian rice production and scope for adaptation. In: *Advances in Agronomy, Vol. 102* [Sparks, D.L. (ed.)]. Academic Press, Burlington, MA, USA, pp. 91-133.
- WCD, 2000: *Dams and Development: A New Framework for Decision-Making*. Report of the World Commission on Dams (WCD), Earthscan Publications, Ltd., London, UK and Sterling, VA, USA, 404 pp.
- Wei, Z., H.J. Jin, J.M. Zhang, S.P. Yu, X.J. Han, Y.J. Ji, R.X. He, and X.L. Chang, 2011: Prediction of permafrost changes in Northeastern China under a changing climate. *Science China: Earth Sciences*, **54**(6), 924-935.
- Wilder-Smith, A., K.E. Renhorn, H. Tissera, S. Abu Bakar, L. Alphey, P. Kittayapong, S. Lindsay, J. Logan, C. Hatz, P. Reiter, J. Rocklöv, P. Byass, V.R. Louis, Y. Tozan, E. Massad, A. Tenorio, C. Lagneau, G. L'Ambert, D. Brooks, J. Wegerdt, and D. Gubler, 2012: Dengue tools: innovative tools and strategies for the surveillance and control of dengue. *Global Health Action*, **5**, 17273, doi:10.3402/gha.v5i0.17273.
- Wilkinson, P., K.R. Smith, M. Davies, H. Adair, B.G. Armstrong, M. Barrett, N. Bruce, A. Haines, I. Hamilton, T. Oreszczyn, I. Ridley, C. Tonne, and Z. Chalabi, 2009: Public health benefits of strategies to reduce greenhouse-gas emissions: household energy. *Lancet*, **374**(9705), 1917-1929.
- Williams, J.W., S.T. Jackson, and J.E. Kutzbach, 2007: Projected distributions of novel and disappearing climates by 2100 AD. *Proceedings of the National Academy of Sciences of the United States of America*, **104**(14), 5738-5742.
- Winkel, L.H.E., T.K.T. Pham, M.L. Vi, C. Stengel, M. Amini, T.H. Nguyen, H.V. Pham, and M. Berg, 2011: Arsenic pollution of groundwater in Vietnam exacerbated by deep aquifer exploitation for more than a century. *Proceedings of the National Academy of Sciences of the United States of America*, **108**(4), 1246-1251.
- Wong, C.-M., T.Q. Thach, P.Y.K. Chau, E.K.P. Chan, R.Y.-N. Chung, C.-Q. Ou, L. Yang, J.S.M. Peiris, G.N. Thomas, T.-H. Lam, T.-W. Wong, and A.J. Hedley, 2010: Part 4. Interaction between air pollution and respiratory viruses: time-series study of daily mortality and hospital admissions in Hong Kong. In: *Public Health and Air Pollution in Asia (PAPA): Coordinated Studies of Short-Term Exposure to Air Pollution and Daily Mortality in Four Cities*. Health Effects Institute (HEI) Research Report 154, HEI Public Health and Air Pollution in Asia Program, HEI, Boston, MA, USA, pp. 283-362.
- Woodcock, J., P. Edwards, C. Tonne, B.G. Armstrong, O. Ashiru, D. Banister, S. Beevers, Z. Chalabi, Z. Chowdhury, A. Cohen, O.H. Franco, A. Haines, R. Hickman, G. Lindsay, I. Mittal, D. Mohan, G. Tiwari, A. Woodward, and I. Roberts, 2009: Public health benefits of strategies to reduce greenhouse-gas emissions: urban land transport. *Lancet*, **374**(9705), 1930-1943.
- Woodward, F.I. and M.R. Lomas, 2004: Vegetation dynamics – simulating responses to climatic change. *Biological Reviews*, **79**(3), 643-670.
- World Bank, 2007: *World Development Report 2008: Agriculture for Development*. The World Bank, Washington, DC, USA, 365 pp.
- World Bank, 2010: *World Development Report 2010: Development and Climate Change*. The World Bank, Washington, DC, USA, 417 pp.
- World Bank, 2011: *World Development Indicators 2011*. The World Bank, Washington, DC, USA, 435 pp.
- World Bank, 2013: *World Development Indicators Database: Gross Domestic Product 2011: GDP per capita (current US\$)*. The World Bank, Washington, DC, USA, data.worldbank.org/indicator/NY.GDP.PCAP.CD.
- Wu, Q.B. and T.J. Zhang, 2010: Changes in active layer thickness over the Qinghai-Tibetan Plateau from 1995 to 2007. *Journal of Geophysical Research: Atmospheres*, **115**(D9), D09107, doi:10.1029/2009JD012974.
- Wu, X.-H., S.-Q. Zhang, X.-J. Xu, Y.-X. Huang, P. Steinmann, J. Utzinger, T.-P. Wang, J. Xu, J. Zheng, and X.-N. Zhou, 2008: Effect of floods on the transmission of schistosomiasis in the Yangtze River valley, People's Republic of China. *Parasitology International*, **57**(3), 271-276.

- Wu, X., H. Liu, D. Guo, O.A. Anenkhonov, N.K. Badmaeva, and D.V. Sandanov, 2012: Growth decline linked to warming-induced water limitation in hemi-boreal forests. *PLoS ONE*, **7(8)**, e42619, doi:10.1371/journal.pone.0042619.
- Wu, Y., R.J. Wang, Y. Zhou, B.H. Lin, L.X. Fu, K.B. He, and J.M. Hao, 2011: On-road vehicle emission control in Beijing: past, present, and future. *Environmental Science & Technology*, **45(1)**, 147-153.
- Wyatt, A.B. and I.G. Baird, 2007: Transboundary impact assessment in the Sesan River Basin: the case of the Yali Falls dam. *Water Resources Development*, **23(3)**, 427-442.
- Xiong, W., I. Holman, E. Lin, D. Conway, J. Jiang, Y. Xu, and Y. Li, 2010: Climate change, water availability and future cereal production in China. *Agriculture, Ecosystems & Environment*, **135(1-2)**, 58-69.
- Xu, G., T. Chen, X. Liu, L. Jin, W. An, and W. Wang, 2011: Summer temperature variations recorded in tree-ring $\delta^{13}\text{C}$ values on the northeastern Tibetan Plateau. *Theoretical and Applied Climatology*, **105(1-2)**, 51-63.
- Xu, J., R.E. Grumbine, A. Shrestha, M. Eriksson, X. Yang, Y. Wang, and A. Wilkes, 2009: The melting Himalayas: cascading effects of climate change on water, biodiversity, and livelihoods. *Conservation Biology*, **23(3)**, 520-530.
- Xu, K., J.D. Milliman, and H. Xu, 2010: Temporal trend of precipitation and runoff in major Chinese Rivers since 1951. *Global and Planetary Change*, **73(3-4)**, 219-232.
- Xu, L., R.B. Myneni, F.S. Chapin III, T.V. Callaghan, J.E. Pinzon, C.J. Tucker, Z. Zhu, J. Bi, P. Ciais, H. Tommervik, E.S. Euskirchen, B.C. Forbes, S.L. Piao, B.T. Anderson, S. Ganguly, R.R. Nemani, S.J. Goetz, P.S.A. Beck, A.G. Bunn, C. Cao, and J.C. Stroeve, 2013: Temperature and vegetation seasonality diminishment over northern lands. *Nature Climate Change*, **3(6)**, 581-586.
- Xu, X., S. Piao, X. Wang, A. Chen, P. Ciais, and R.B. Myneni, 2012: Spatio-temporal patterns of the area experiencing negative vegetation growth anomalies in China over the last three decades. *Environmental Research Letters*, **7(3)**, 035701, doi:10.1088/1748-9326/7/3/035701.
- Yamanaka, T., Y. Wakiyama, and K. Suzuki, 2012: Is snowmelt runoff timing in the Japanese Alps region shifting toward earlier in the year? *Hydrological Research Letters*, **6**, 87-91, doi:10.3178/HRL.6.87.
- Yamano, H., K. Sugihara, and K. Nomura, 2011: Rapid poleward range expansion of tropical reef corals in response to rising sea surface temperatures. *Geophysical Research Letters*, **38(4)**, L04601, doi:10.1029/2010GL046474.
- Yang, B., C. Qin, K. Huang, Z.X. Fan, and J.J. Liu, 2010: Spatial and temporal patterns of variations in tree growth over the northeastern Tibetan Plateau during the period AD 1450-2001. *Holocene*, **20(8)**, 1235-1245.
- Yang, Z.-p., J.-x. Gao, L. Zhao, X.-I. Xu, and H. Ouyang, 2013: Linking thaw depth with soil moisture and plant community composition: effects of permafrost degradation on alpine ecosystems on the Qinghai-Tibet Plateau. *Plant and Soil*, **367(1-2)**, 687-700.
- Yao, T., L. Thompson, W. Yang, W. Yu, Y. Gao, X. Guo, X. Yang, K. Duan, H. Zhao, B. Xu, J. Pu, A. Lu, Y. Xiang, D.B. Kattel, and D. Joswiak, 2012: Different glacier status with atmospheric circulations in Tibetan Plateau and surroundings. *Nature Climate Change*, **2(9)**, 663-667.
- Yao, X.-J., S.-Y. Liu, W.-Q. Guo, B.-J. Huai, M.-P. Sun, and J.-L. Xu, 2012: Glacier change of Altay Mountain in China from 1960 to 2009 – based on the Second Glacier Inventory of China. *Journal of Natural Resources*, **27(10)**, 1734-1745 (in Chinese).
- Yara, Y., M. Vogt, M. Fujii, H. Yamano, C. Hauri, M. Steinacher, N. Gruber, and Y. Yamanaka, 2012: Ocean acidification limits temperature-induced poleward expansion of coral habitats around Japan. *Biogeosciences*, **9(12)**, 4955-4968.
- Yi, L., W. Jiao, X. Chen, and W. Chen, 2011: An overview of reclaimed water reuse in China. *Journal of Environmental Sciences*, **23(10)**, 1585-1593.
- Yi, O., Y.-C. Hong, and H. Kim, 2010: Seasonal effect of PM₁₀ concentrations on mortality and morbidity in Seoul, Korea: a temperature-matched case-crossover analysis. *Environmental Research*, **110(1)**, 89-95.
- Yu, D., M. Chen, Z. Zhou, R. Eric, Q. Tang, and H. Liu, 2013: Global climate change will severely decrease potential distribution of the East Asian coldwater fish *Rhynchocypris oxycephalus* (Actinopterygii, Cyprinidae). *Hydrobiologia*, **700(1)**, 23-32.
- Yu, H., E. Luedeling, and J. Xu, 2010: Winter and spring warming result in delayed spring phenology on the Tibetan Plateau. *Proceedings of the National Academy of Sciences of the United States of America*, **107(51)**, 22151-22156.
- Yu, H., J. Xu, E. Okuto, and E. Luedeling, 2012: Seasonal response of grasslands to climate change on the Tibetan Plateau. *PLoS ONE*, **7(11)**, e49230, doi:10.1371/journal.pone.0049230.
- Yu, X., L. Jiang, L. Li, J. Wang, L. Wang, G. Lei, and J. Pittock, 2009: Freshwater management and climate change adaptation: experiences from the central Yangtze in China. *Climate and Development*, **1**, 241-248.
- Yu, Z., S. Liu, J. Wang, P. Sun, W. Liu, and D.S. Hartley, 2013a: Effects of seasonal snow on the growing season of temperate vegetation in China. *Global Change Biology*, **19(7)**, 2182-2195.
- Yu, Z., P. Sun, S. Liu, J. Wang, and A. Everman, 2013b: Sensitivity of large-scale vegetation greenup and dormancy dates to climate change in the North-South Transect of Eastern China. *International Journal of Remote Sensing*, **34(20)**, 7312-7328.
- Zeller, D., S. Booth, E. Pakhomov, W. Swartz, and D. Pauly, 2011: Arctic fisheries catches in Russia, USA, and Canada: baselines for neglected ecosystems. *Polar Biology*, **34(7)**, 955-973.
- Zeng, X.D., X.B. Zeng, and M. Barlage, 2008: Growing temperate shrubs over arid and semiarid regions in the Community Land Model-Dynamic Global Vegetation Model. *Global Biogeochemical Cycles*, **22(3)**, GB3003, doi:10.1029/2007GB003014.
- Zhang, G., Y. Zhang, J. Dong, and X. Xiao, 2013: Green-up dates in the Tibetan Plateau have continuously advanced from 1982 to 2011. *Proceedings of the National Academy of Sciences of the United States of America*, **110(11)**, 4309-4314.
- Zhang, L., H. Guo, L. Ji, L. Lei, C. Wang, D. Yan, B. Li, and J. Li, 2013: Vegetation greenness trend (2000 to 2009) and the climate controls in the Qinghai-Tibetan Plateau. *Journal of Applied Remote Sensing*, **7(1)**, 073572, doi:10.1117/1.JRS.7.073572.
- Zhang, N., T. Yasunari, and T. Ohta, 2011: Dynamics of the larch taiga-permafrost coupled system in Siberia under climate change. *Environmental Research Letters*, **6(2)**, 024003, doi:10.1088/1748-9326/6/2/024003.
- Zhang, T., J. Zhu, and R. Wassmann, 2010: Responses of rice yields to recent climate change in China: an empirical assessment based on long-term observations at different spatial scales (1981–2005). *Agricultural and Forest Meteorology*, **150(7-8)**, 1128-1137.
- Zhang, Y., B. Peng, and J.E. Hiller, 2008: Weather and the transmission of bacillary dysentery in Jinan, northern China: a time-series analysis. *Public Health Reports*, **123(1)**, 61-66.
- Zhao, L., Q.B. Wu, S.S. Marchenko, and N. Sharkhuu, 2010: Thermal state of permafrost and active layer in Central Asia during the International Polar Year. *Permafrost and Periglacial Processes*, **21(2)**, 198-207.
- Zheng, M., 2011: Resources and eco-environmental protection of salt lakes in China. *Environmental Earth Sciences*, **64(6)**, 1537-1546.
- Zhou, J., X. Zhang, M. Chen, X. Huang, A. Liu, T. Yang, and H. Tan, 2011: Epidemiological study on hemorrhagic fever with renal syndrome in flood areas. *Journal of Central South University*, **36(3)**, 223-228.
- Zhou, S.S., F. Huang, J. Wang, S. Zhang, Y. Su, and L. Tang, 2010: Geographical, meteorological and vectorial factors related to malaria re-emergence in Huang-Huai River of central China. *Malaria Journal*, **9**, 337, doi: 10.1186/1475-2875-9-337.
- Zhou, X.-N., G.-J. Yang, K. Yang, X.-H. Wang, Q.-B. Hong, L.-P. Sun, J.B. Malone, T.K. Kristensen, N.R. Bergquist, and J. Utzinger, 2008: Potential impact of climate change on schistosomiasis transmission in China. *The American Journal of Tropical Medicine and Hygiene*, **78(2)**, 188-194.
- Ziv, G., E. Baran, S. Nam, I. Rodríguez-Iturbe, and S.A. Levin, 2012: Trading-off fish biodiversity, food security, and hydropower in the Mekong River Basin. *Proceedings of the National Academy of Sciences of the United States of America*, **109(15)**, 5609-5614.
- Zuidema, P.A., P.J. Baker, P. Groenendijk, P. Schippers, P. van der Sleen, M. Vlam, and F. Sterck, 2013: Tropical forests and global change: filling knowledge gaps. *Trends in Plant Science* **18(8)**, 413-419.