Implications of international climate change impacts for Finland (IMPLIFIN)

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Summary

In Finland there has been substantial research on the impacts of climate change on the Finnish environment and society. There have been fewer studies on the implications of climate change impacts elsewhere in the world for Finland. However, climate change impacts on the world economy and on the development of poorer countries could have repercussions for the Finnish economy and for Finland's international relations in general. Furthermore, international climate policy and especially EU regulations will have implications for Finnish policy making. Indeed, in the long run, impacts that are external to Finland could prove to be more significant for policy makers than domestic concerns.

The Finnish National Adaptation Strategy identified some of the global impacts, but so far the implications of global climate change impacts for Finland have not been studied. Special consideration in this study is accorded those world regions and countries that Finland has connections to, either through trade, investments, tourism or as development co-operation partners. The study concentrates on those sectors considered to be most sensitive to the international impacts of climate change. Some issues relating to security, forced migration and dangerous levels of climate change are also discussed.

Climate change impacts will not be evenly distributed throughout the world. Some regions and countries will be more seriously affected than others, and many of the countries that will face the most adverse effects are in the developing world. These are commonly countries that are currently vulnerable to climate variability, where climate change can exacerbate already existing problems, changing conditions in some areas to the extent that they become unsuitable for living. Conflicts and forced migration could follow, though there is usually more than one single cause for outbreaks of violent conflicts or people forced to leave their homes. On the other hand, it should also be noted that some areas may find themselves exposed to more favourable climates in the future than at present, and it is possible that such areas might eventually attract migrants, maybe in larger numbers than today.

Agriculture is considered to be one of the sectors in Finland that could be affected by climate change impacts elsewhere in the world, through mechanisms such as major food production areas losing some of their production potential, changes in demand for agricultural products and implications of mitigation measures such as increased demand for bio-energy crops. However, other factors than climate change have a strong influence on agricultural production in Finland and on its competitive position, including the changing competitive position of agriculture in Eastern Europe, land use and land prices, and agricultural policy.

Climate change can affect the forestry sector through international climate policies, such as changing demand for forest bioenergy and the importance of forests as carbon sinks. The use of Finnish forests may be affected by changes in the pattern of nature-based tourism, and Finnish forest industries can also be affected by global climate change impacts on their investments abroad.

The Finnish tourism sector could also be affected by climate change, both due to changes in conditions at home as well as changes at popular overseas destinations. If tourists switch their holiday destinations, there will be implications both for the current destinations (such as the Mediterranean and the Alps) as well as for Finland itself. How large the distributional impacts will be depends on the adaptation of tourists, tourist businesses and societies.

For the energy sector, there can be implications through changing international and EU policies. Climate change can also have impacts on energy production in the countries that Finland imports energy from. For example, hydropower production is expected to increase in Fennoscandia. On the other hand, energy infrastructure, and particularly transmission networks and pipelines, are likely to be vulnerable to climate change, especially to changes in extreme weather events. Climate change could affect the reliability of distribution and therefore energy supply in Finland.

The opening of the two major northern sea routes – the Northwest Passage and Northern Sea Route – would have large implications for commercial activity in the Arctic. There could be substantial savings in transportation costs, as well as savings in time and energy costs. There is also a military and strategic dimension to the opening of new sea routes, which could alter the world's geopolitical balance. For Finland, the opening of the Arctic Sea routes could mean increased transportation through Northern Finland and Lapland and possibly also changes in marine transportation in the Gulf of Bothnia or in the Baltic Sea in general.

In the early stages of global warming, the impacts of changes on average climate on the Finnish economy are not expected to be very large, with beneficial impacts approximately compensating for detrimental impacts. Moreover, the near-term adaptive capacity of Finland appears to be quite high, especially when compared to poorer countries. The aggregate economic impacts of climate change on Finland are estimated to be rather modest in the short term, and could even be slightly positive if the potential benefits can be successfully exploited and costs attenuated. Climate change-induced changes in foreign trade are likely to be an important source of economic impacts for Finland. Effects can be mixed and benefits could occur in some periods and negative effects in others. However, extreme weather events could increase costs significantly, and have yet been properly assessed.

It is estimated that climate change mitigation will bring additional challenges to the Finnish economy as significant mitigation levels would require large structural changes in Finland. However, if mitigation measures were gradual rather than abrupt, the impacts to the economy would be smaller. In addition to costs, there are also benefits as a consequence of climate policies. The benefits of mitigation policies could include avoided damages and ancillary benefits such as better air quality. Climate change policies can also create new employment, for example, through energy efficiency improvements and new technologies. Climate mitigation that reduces dependence on fossil fuels for energy would also avoid costs associated with transport of fossil fuels about the globe. For example, oil pollution incidents could be avoided and significant benefits to energy security could also be achieved.

Most of the Finnish development co-operation partner countries are very vulnerable to the impacts of climate change. Climate change could have serious implications for their development and could endanger the achievement of sustainable development. It is already recognised that development co-operation policies and practices need to be modified to take climate change into account. There is a need to mainstream climate change issues into Finnish development co-operation strategies, plans and measures, and to take the issue into consideration for example in planning of foreign investments.

1. Introduction

The climate of the earth is changing. The Intergovernmental Panel on Climate Change (IPCC) reports that the global average surface air temperature has increased 0.74°C (± 0.18ºC) during the past 100 years (IPCC 2007a) and evidence shows that many natural and human systems are already being affected by climate changes (IPCC 2007b). For the next two decades, the IPCC projects a warming of about 0.2ºC per decade. Continued greenhouse gas emissions at or above current rates are expected to cause further warming and induce many changes in the global climate system during this century. Very likely the changes would be larger than the ones experienced during the last century (IPCC, 2007a). Climate change will affect a wide range of natural systems in all world regions (IPCC 2007b). Impacts are expected to increase in magnitude with increases in global average temperature and while they will vary regionally, they are very likely to impose costs which will increase over time as global temperature increases.

Climate change is not the only environmental change being experienced (Figure 1), and vulnerability of a system or region to climate change may be exacerbated by the presence of other stresses. For instance, the Millennium Ecosystem Assessment (MA) projects that, at least during the first half of this century, land use change and primarily the continuing expansion of agriculture will continue to be a major direct driver of biodiversity change in terrestrial and freshwater ecosystems, followed by changes in climate and nitrogen deposition (Millennium Ecosystem Assessment 2005).

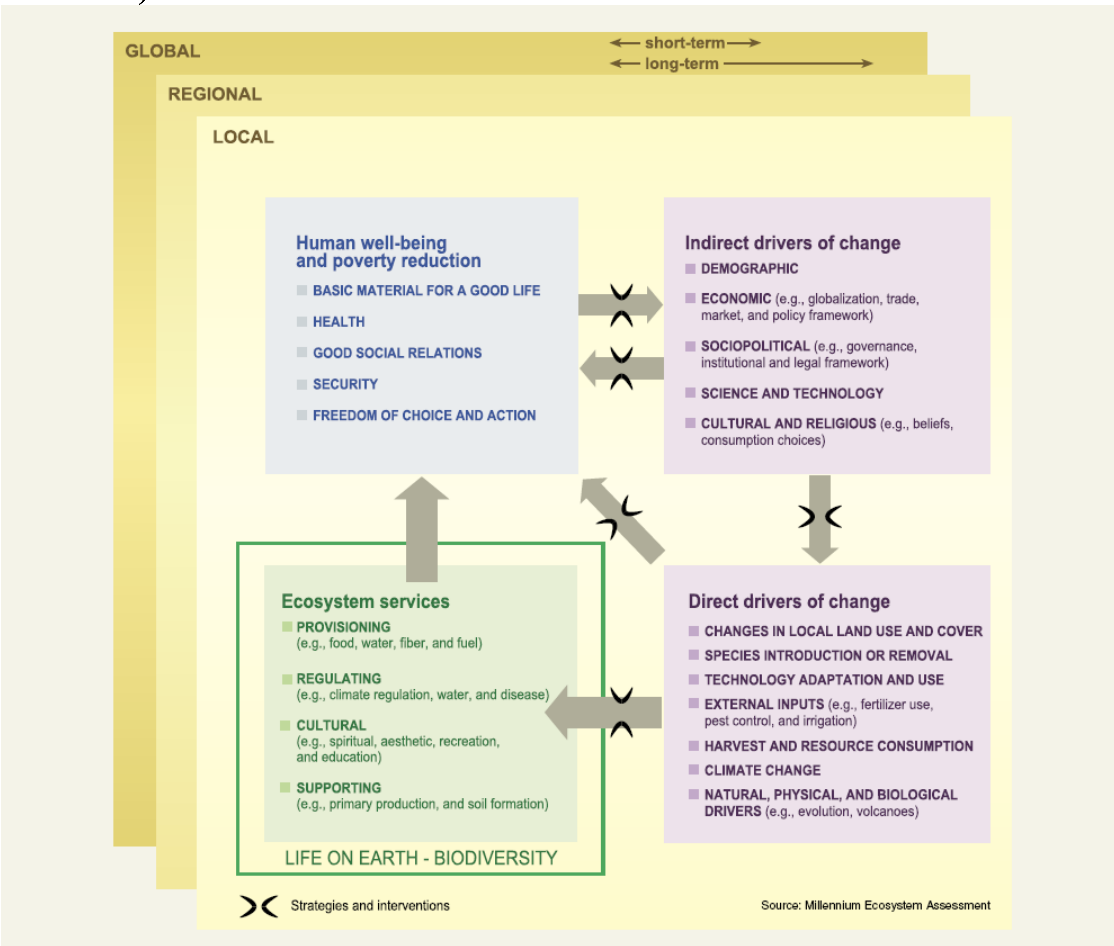

Figure 1 Conceptual framework of interactions between biodiversity, ecosystem services, human well-being and drivers of change (Millennium Ecosystem Assessment 2005).

Vulnerable regions often face multiple stresses that affect their exposure and sensitivity to climate change as well as their capacity to adapt. These stresses arise, for example, from current climate hazards, poverty and unequal access to resources, food insecurity, trends in economic globalisation, conflict and incidence of disease such as HIV/AIDS. Non-climate stresses can increase vulnerability by reducing resilience and can also reduce adaptive capacity because of resource deployment to competing needs. (IPCC 2007b, 18).

The MA projects that human use of ecosystem services will increase substantially during the next 50 years. In many cases this will be accompanied by a degradation of the quality and sometimes a reduction in the quantity of the service available. The combination of growing populations and growing per capita consumption increases the demand for ecosystem services, including water and food. For example, the demand for food crops is expected to grow by 70-85% by 2050 and global water withdrawals to increase by 20-85%. Ecosystem services that are projected to be further impaired by ecosystem change include fisheries, food production in drylands, quality of fresh waters and cultural services. (Millennium Ecosystem Assessment 2005, 80)

In Finland there has already been substantial research on the impacts of climate change on the Finnish environment and society (e.g. Martilla et al. 2005; Carter, 2007). This indicates that in the near future, and if climate change is not very large, there could be mixed impacts. Some impacts could be beneficial, such as increased growth of forests, but others negative, for example increased risks of flooding and droughts. Climate change is a global phenomenon, however, and impacts elsewhere in the world will also have implications for Finland. For example, climate change can have impacts on the world economy and on the development of poorer countries, which could then have repercussions for the Finnish economy. Furthermore, international climate policy and especially EU regulations will have implications for Finnish policy making. As well as a need to limit greenhouse gas emissions through mitigation measures, adaptation to emerging or prospective impacts will also be required, and some of these impacts will occur outside Finland. The Finnish National Adaptation Strategy identified some of the global impacts, but so far the implications of global climate change impacts for Finland have not been studied. Some assessments, such as the Stern review (Stern, 2005) and OECD (2004) have assessed the global costs and impacts of climate change, but these do not discuss implications from a single country perspective.

The purpose of this study is to review, in more detail than was possible for the National Strategy, the possible implications for Finland of the international impacts of a changing climate. It has two objectives:

1. To summarise the most likely impacts outside Finland, at global scale and for Europe, of long-term climate change and related changes in extreme climate events;
2. To identify links between impacts occurring outside Finland and their likely consequences for Finland, both through their indirect impacts on Finland as well as through their implications for international policy making.

The focus in this study is on those world regions and countries that Finland has connections to, either through trade, investments, tourism or as development co-operation partners. The study concentrates on those sectors considered to be most sensitive to the international impacts of climate change: mainly agriculture, forestry, water resources, energy and tourism and considers the implications for development co-operation and international policy making. Some issues relating to security and dangerous levels of climate change are also discussed and some further research needs are identified.

Section 2 first provides background information on some of the ongoing international policy processes in which Finland participates that explicitly address climate change. The following sections then offer a summary of the scientific knowledge about climate change, its impacts, risks and vulnerabilities. Section 3 reports changes that have already been observed during past decades, Section 4 describes impacts that are projected to occur globally and in different regions of the world under alternative scenarios for the present century, while Section 5 focuses on some key risks and vulnerabilities associated with climate change, including their security implications. The possible impacts of global climate change on the Finnish economy, foreign trade and investments is examined in Section 6, and the vulnerability of Finland's development co-operation partners to climate change is surveyed in Section 7. Finally, the concluding section attempts to identify some of the key messages for policy that emerge from this review of the international impacts of climate change.

2. International climate change policy processes

2.1. The UN Framework Convention on Climate Change

The UN Framework Convention on Climate Change (UNFCCC) was signed by most of the world's governments in 1992, at the Earth Summit in Rio de Janeiro. Currently more than 175 countries have ratified the convention, including all large industrialised countries. UNFCCC set as its long term objective "the stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic intervention with the climate system. Such a level should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner"

The first legally binding outcome of the UNFCCC was the agreement in 1997 of a supplement to the climate convention, called the Kyoto Protocol, which came into force in 2005. The Protocol agreed targets for emissions of six key greenhouse gases: carbon dioxide, methane, nitrous oxide, and three groups of fluorinated gases. The targets apply to 35 industrialised countries (Annex I parties) and refer to the period 2008-2012. The commitment of the industrialised countries as a whole, is to reduce their emissions of the six greenhouse gases to 5.2% below 1990 levels by the period 2008-2012. Countries should meet their targets by cutting domestic emissions but are also entitled to use the Protocol's so called flexible mechanisms. These include Joint Implementation (JI) and the Clean Development Mechanism (CDM). Countries are also allowed to use increasing carbon uptake by forests and other ecosystem sinks.

Article 12 of the Convention requires all parties to report on the steps they are taking to implement the Convention. The reports[1] include National Communications, greenhouse gas inventories and National Adaptation Programmes of Action (NAPAs). In the National Communications, all parties should report on the steps they are taking to implement Articles 4.1 (Commitments) and 12 (Implementation) of the Convention. The required contents of National Communications and the timetable for their submission is different for Annex I and non-Annex I Parties. The first National Communications by Annex I parties were submitted in 1994 – 1995. The fourth national communications were due on 1 January 2006. Annex I Parties should also submit an annual inventory of their greenhouse gas emissions to the secretariat.

National Adaptation Programmes of Action (NAPA[2]) is a process in which the Least Developed Countries (LDCs) identify priority adaptation activities. The LDCs have limited ability to adapt to the adverse effects of climate change and a new approach was needed to address the urgent adaptation needs of LDCs. NAPAs focus on enhancing adaptive capacity to climate variability, which itself would help address the adverse effects of climate change. Existing coping strategies at the grassroots level are taken into account, and priority activities are identified. In the NAPA process, prominence is given to community-level input as an important source of information, as grassroots communities are the main stakeholders.

A recent initiative under the UNFCCC is the Nairobi Work Programme[3] on impacts, vulnerability and adaptation to climate change. This is a five-year programme to assist countries, in particular developing countries, to improve their understanding and assessment of impacts, vulnerability and

[1] http://unfccc.int/national_reports/items/1408.php
[2] http://unfccc.int/national_reports/napa/items/2719.php
[3] http://unfccc.int/adaptation/sbsta_agenda_item_adaptation/items/3633.php

adaptation, and to make informed decisions on practical adaptation actions and measures to respond to climate change. The NWP is organised around nine areas: methods and tools, data and observations, climate modelling and scenarios, climate related risks and extreme events, socio-economic information, adaptation planning and practices, research, technologies for adaptation and economic diversification.

2.2. Other international policy initiatives

The European Union accepted an 8% common greenhouse gas emissions reduction target at Kyoto in 1997 and there is a burden sharing agreement between the member countries. As part of the effort to reach the Kyoto target, the EU has introduced an emissions trading system, which is already operating.

In January 2007, the European Commission set out proposals and options for keeping climate change to manageable levels in its Communication "Limiting Global Climate Change to 2° Celsius: The way ahead for 2020 and beyond" (Commission of the European Communities 2007a). The Communication is part of a package of measures to establish a new energy policy for Europe, and a contribution to the discussions at international level on a future global agreement to combat climate change after 2012, when the Kyoto Protocol's emissions targets expire. The Communication proposes a set of actions by developed and developing countries that would limit global warming to no more than 2°C above pre-industrial levels. The key elements of the Communication were endorsed by EU Environment Ministers on 20 February 2007 and considered by EU leaders at their Spring summit in Brussels on 8-9 March 2007.

The European Commission adopted its first policy document on adaptation to climate change in June 2007 (Commission of the European Communities 2007b). The Green Paper[4] (Adapting to climate change in Europe - options for EU action) builds upon the work and findings of the European Climate Change Programme. The paper describes possible avenues for action at EU level. The main objective of the Paper is to start discussion and consultation on the issue at the European level.

At a G8 summit in Germany June 8, 2007[5] the G8 countries[6], Brazil, China, India, Mexico and South Africa gave a joint statement on fighting climate change. The countries "remain committed to contribute their fair share to tackle climate change in order to stabilise greenhouse gas concentrations at a level that would prevent dangerous anthropogenic interference with the climate system." The G8 did not agree on a global target, however, but welcomes a global framework and concerted international action. The G8 underlines the role of economic incentives, in particular carbon markets. Adaptation is considered a major challenge for all countries and in particular for developing countries, and means for adaptation need to be included in a future agreement along with enhanced technology co-operation and financing.

Climate change will be a central issue in Nordic co-operation over the coming years, especially as the UNFCCC Conference of the Parties is to be held in Copenhagen in 2009. The Nordic Council's climate group has worked with current climate and energy issues since 1996. In 2007, the Nordic Council of Ministers published a report on Nordic research co-operation on climate change and its impacts in the Arctic and co-organised a seminar in Helsinki on "Planning for climate change".

[4] http://ec.europa.eu/environment/climat/adaptation/index_en.htm
[5] http://unfccc.int/meetings/items/4029.php
[6] Eight of the major industrialised countries: Canada, France, Germany, Italy, Japan, Russia, UK and USA

The Baltic Sea Experiment (BALTEX) is a continental-scale experiment of the Global Energy and Water Cycle Experiment (GEWEX), part of the World Climate Research Programme (WCRP). BALTEX, launched in 1992, is concerned with the Baltic Sea and its catchment area, and during 2007 has carried out the BALTEX Assessment of Climate Change (BACC) for the Baltic Sea basin in co-operation with HELCOM, the Helsinki Commission, Baltic Marine Environment Protection Commission. BACC assembles, integrates and assesses available knowledge of past, current, and expected future climate change and its impacts on ecosystems in the Baltic Sea basin. The BACC assessment will be published as a book and HELCOM (2007) has published a thematic assessment on climate change in the Baltic Sea area, based on the BACC work.

Finally, the Arctic Council has launched a project on vulnerability and adaptation in the Arctic region (2007-2008). Data on adaptation practices and measures in the Arctic region will be collected and an expert workshop organised in 2008.

2.3. Policy processes supported by international and multilateral agencies

Many multilateral agencies and overseas development programmes are taking climate change into account in their work. For example, the African Development Bank, the Asian Development Bank, the World Bank, UNEP, and the governments of the UK and Germany have produced the Interagency Poverty and Climate Change Report (African Development Bank et al. 2003).

A recent OECD project had as its main objective an exploration of synergies and trade-offs in mainstreaming responses to climate change in development assistance policies of donor agencies, as well as national and sectoral policies of recipient countries (OECD 2005). The OECD has also analysed the broad trends in progress on adaptation to climate change in developed countries and linking climate change and development (OECD 2006). Other OECD studies on responses to climate change include a report on climate change and the European Alps (2007) and policy frameworks for adaptation in the water sector and coastal zones (Levine and Adams 2006, Levine 2006, Levine et al. 2006).

The World Bank recognises the threat posed by climate change to the development process, and seeks to support and facilitate the mainstreaming of climate change concerns in the development agenda It has published several reports on integrating vulnerability and adaptation to climate change into the Bank's work (Van Aalst and Burton 1999, 2004; World Bank 2006; Mathen et al. 2004). The World Bank has also produced many reports on adapting to natural hazards and disaster risk management (e.g. World Bank 2005, 2006a,b,c; Kryspin-Watson et al. 2006).

The United Nations Environment Programme (UNEP) has a key role in a broad range of activities related to understanding, mitigating and adapting to climate change[7]. UNEP works in several focal areas related to climate change issues including mitigation, carbon sequestration, adaptation and vulnerability, technology transfer and capacity building. UNEP has three climate change centres: GRID ARENDAL (Global Environmental Information on Climate Change, based in Norway), UNEP Risøe Centre in Denmark, which is responsible for the project Capacity Development for the CDM (CD4CDM), and UNEP-WCMC (World Conservation Monitoring Centre, based in the UK).

The United Nations Development Programme (UNDP) is supporting developing countries in responding to climate change concerns as part of their overall sustainable development efforts[8].

[7] http://www.unep.org/themes/climatechange/index.asp
[8] http://www.undp.org/climatechange/

UNDP works with developing countries to create integrated solutions to social, economic and environmental challenges, with a primary focus on improving the lives of those living in extreme poverty. Given UNDP's focus on poverty alleviation, and the disproportionate impacts of climate change on the poorest countries, UNDP's work with developing countries on adopting climate change adaptation and mitigation measures concentrates on those measures that reduce the vulnerability of the poor and expand opportunities for sustainable livelihoods. In 2005 UNDP published an adaptation policy framework (APF) that is intended to help provide a much-needed roadmap for the rapidly evolving process of adaptation policy-making (UNDP 2005)[9].

The UNDP-Global Environment Facility (GEF) is a fund that supports the development of projects in the focal areas of biodiversity, climate change, international waters, land degradation, persistent organic pollutants and ozone depletion. GEF projects in climate change help developing countries and economies in transition to contribute to the overall objective of the UNFCCC. The projects support measures that minimise climate change damage by reducing risks or the adverse effects of climate change. GEF supports both mitigation and adaptation projects.

[9] http://www.undp.org/gef/adaptation/climate_change/APF.htm

3. Observations of global climate change and its impacts

3.1. Observed changes in climate

The IPCC Fourth Assessment Report provides a comprehensive review of observed changes in the surface climate of the Earth during the instrumental record stretching back to the middle of the 19th century (Trenberth et al., 2007). Their major findings are summarised by Solomon et al. (2007), and a subset of these results are reproduced here.

The global average surface air temperature has increased by about 0.74ºC during the past 100 years (Figure 2). The rate of warming averaged over the last 50 years (about 0.13ºC per decade) is nearly twice that for the last 100 years. Eleven of the last twelve years (1995 to 2006) rank among the 12 warmest years on record since 1850, the two warmest being 2005 and 1998. During this period, surface temperatures over land regions have warmed at a faster rate than over the oceans in both hemispheres. Warming over land has also been at a significantly faster rate than over oceans in the past two decades.

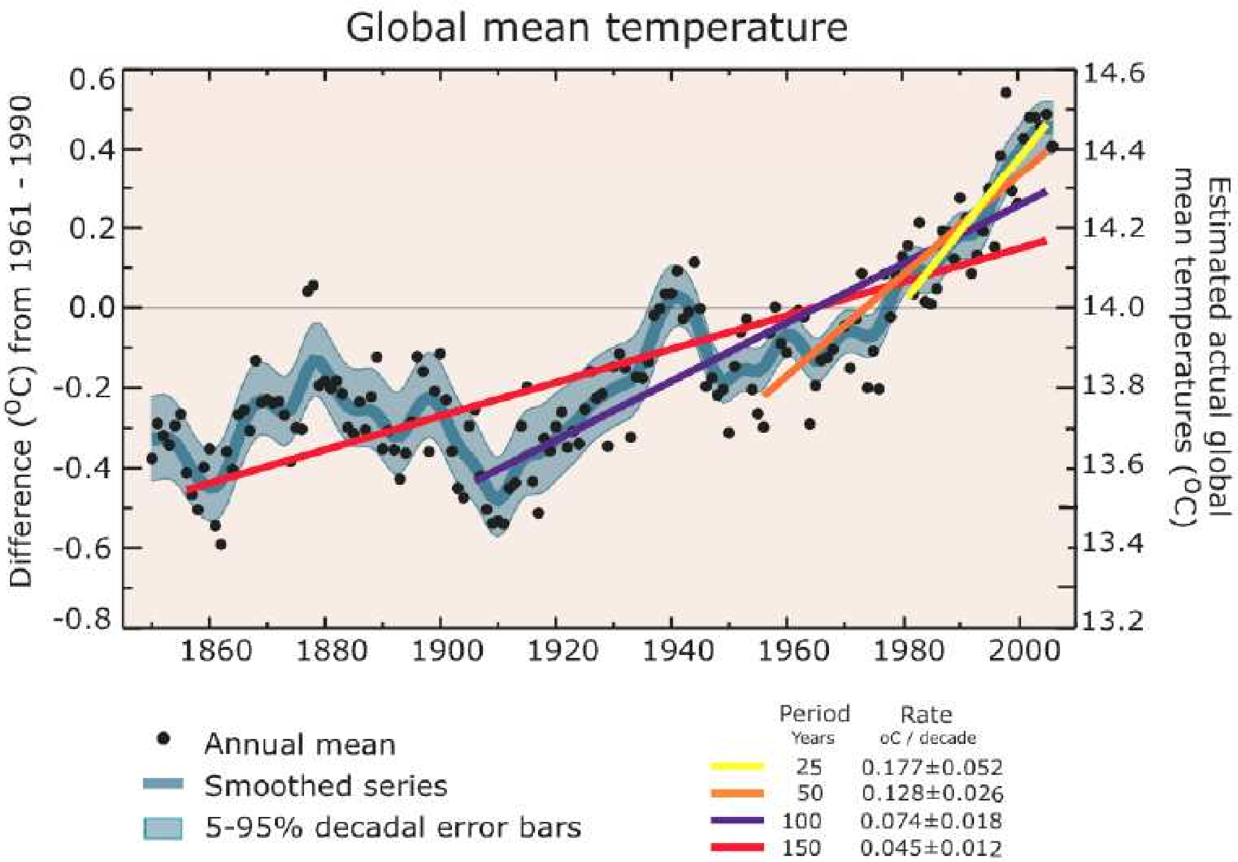

Figure 2 Annual global mean temperatures 1850 to 2005 (black dots) with linear fits to the data. The left hand axis shows temperature anomalies relative to the 1961 to 1990 average and the right hand axis shows estimated actual temperatures, both in °C. Linear trends are shown for the last 25 (yellow), 50 (orange), 100 (magenta) and 150 years (red). The smooth blue curve shows decadal variations, with the decadal 90% error range shown as a pale blue band about that line. The total temperature increase from the period 1850 to 1899 to the period 2001 to 2005 is 0.76°C ± 0.19°C (Source: Trenberth et al., 2007).

The warming has been greatest at higher northern latitudes, where the greatest warming has occurred during winter and spring. Average Arctic temperatures have been increasing at almost twice the rate of the rest of the world in the past 100 years. In mid-latitude regions, widespread reductions have been observed in the number of frost days, increases in the number of warm extremes (warmest 10% of days or nights) and a reduction in the number of daily cold extremes (coldest 10% of days or nights).

During the period 1901 – 2005 significantly increased precipitation has been observed in eastern parts of North and South America, northern Europe and northern and central Asia (Figure 3). Drying has been observed in the Sahel, the Mediterranean, southern Africa and parts of southern Asia. More intense and longer droughts have been observed over wider areas, particularly in the tropics and subtropics since the 1970s. Increased drying due to higher temperatures and decreased land precipitation have contributed to these changes.

There is evidence that the number and proportion of tropical cyclones reaching the most intense categories has increased since 1970. There is no clear trend observed in the total number of tropical cyclones.

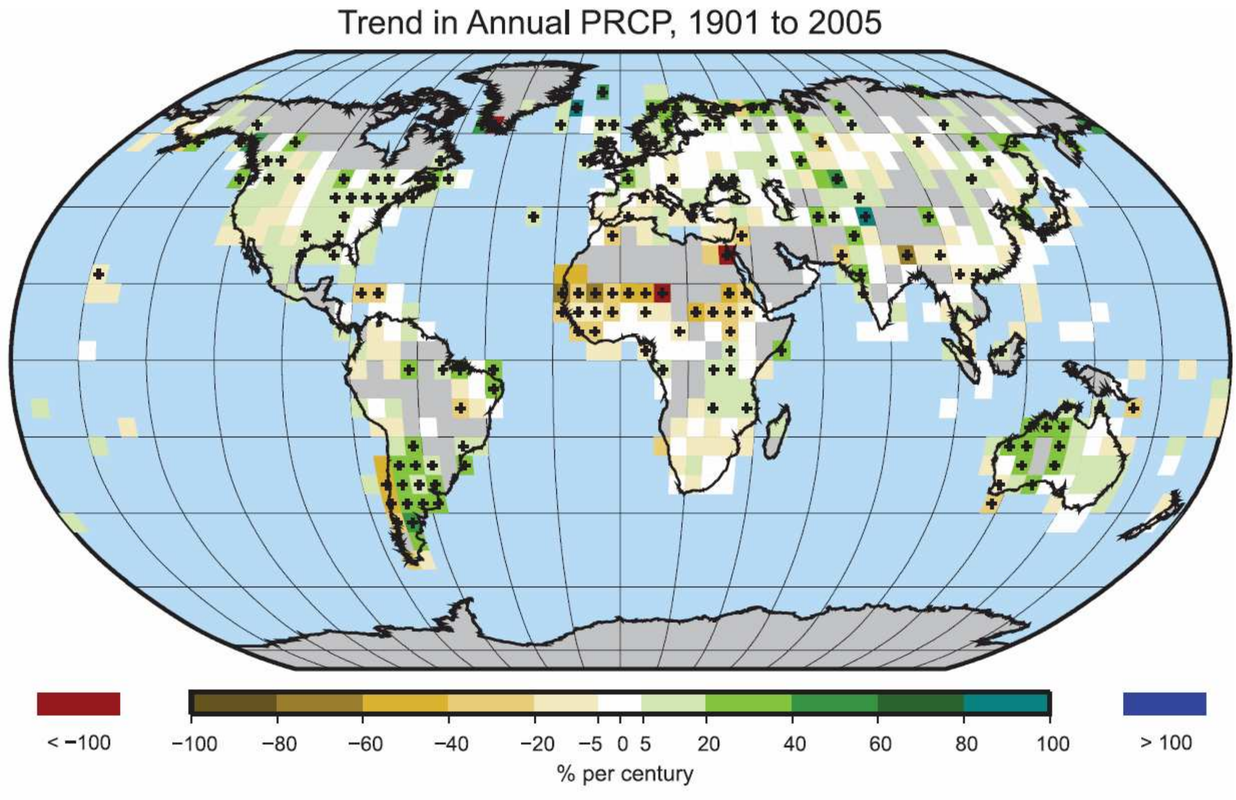

Figure 3 Distribution of linear trends of annual land precipitation amounts over the period 1901 to 2005 (% per century). Areas in grey have insufficient data to produce reliable trends. The percentage is based on the 1961 to 1990 period (Source: Trenberth et al., 2007).

3.2. Observed impacts

The IPCC also reports that there is very high confidence, based on observational evidence from all continents and most oceans, that many natural systems are being affected by regional climate changes, particularly temperature increases (Rosenzweig et al., 2007). In summarising their findings, Parry et al. (2007) describe:

- Strong evidence that climate change is already affecting natural and managed systems in the cryosphere (regions with snow and ice). The physical evidence includes: ground instability in mountain and permafrost regions, ice and rock avalanches, increase and enlargement of glacial lakes and destabilisation of moraines damming these lakes, with increased risk of outburst floods. Changes in Arctic and Antarctic Peninsula flora and fauna have been observed, including sea-ice biomes and species high on the food chain. There have also been limitations on mountain sports in lower-elevation alpine areas.
- Evidence of effects on hydrology and water resources, coastal zones, and oceans. For example, the spring peak discharge is occurring earlier in rivers affected by snow melt, and there is evidence for enhanced glacial melt in the tropical Andes and in the Alps. Lakes and rivers around the world are warming, with effects on thermal structure and water quality. Evidence of responses of terrestrial species in the Northern Hemisphere include changes in the timing of growth stages, especially the earlier onset of spring events, migration and lengthening of the growing season. There have been trends in many regions towards earlier greening of vegetation in the spring and increased net primary production linked to longer growing seasons and increasing CO_2 concentrations. Warming of lakes and rivers is affecting abundance and productivity, community composition, phenology, and distribution and migration of freshwater species. Sea-level rise and human development are together contributing to losses of coastal wetlands and mangroves and increasing damage from coastal flooding in many areas.

Effects of regional warming on managed and human systems are more difficult to discern than effects of warming on natural systems (Rosenzweig et al. 2007; Parry et al. 2007). However, effects have been detected in agricultural and forestry systems. The lengthening of the growing season has contributed to an observed increase in forest productivity and increased forest fires in North America and the Mediterranean basin, whilst altered phenology has resulted in some limited crop management responses, such as earlier spring planting in northern higher latitudes. Both agriculture and forestry have shown vulnerability to recent trends in heat waves, droughts and floods.

It is important to point out that the majority of studies assessed by the IPCC are from mid and high latitudes in the Northern Hemisphere. Documentation of observed changes in tropical regions and the Southern Hemisphere is sparse.

4. Projected climate change and its impacts on world regions

This section is divided into two parts. First, projections of global climate change are presented. Second, regional projected climate and some of its impacts are depicted for seven world regions (Europe, North America, Latin America, Africa, Asia, Australia and New Zealand, and the Arctic region). The regions are chosen on the basis of their significance to Finland. Therefore two world regions that the IPCC includes in its analysis and reporting are not covered here, namely Small Islands and the Antarctic. In Section 7, projected impacts of climate change are described in more detail for Finland's development co-operation partner countries.

4.1. Global climate projections

The likely (probability > 66%) range of projected globally-averaged surface warming by the end of the 21st century (2090-2099) relative to 1980-1999 across six SRES marker scenarios[10] varies from 1.1 – 2.9°C for the B1 scenario to 2.4 – 6.4ºC for the A1FI scenario (Meehl et al. 2007 – grey bars in Figure 4). The temperature change projected for this century is positive across all regions of the earth. It increases as one moves away from coasts and into the continental interiors and is at a maximum in high latitudes and over land in Northern hemisphere during winter. Warming is also typically larger in arid than in moist regions. Warming is projected to be least over the southern oceans and the North Atlantic (Solomon et al. 2007 – see left hand panels of Figure 5).

By the end of the 21st century the projected probability of extreme warm seasons[11] rises above 90% in many tropical areas, and reaches around 40% elsewhere. In a future climate, heat waves are expected to be more intense, longer-lasting and more frequent. They are projected to increase globally and over most regions. On the other hand, models project a decline in the frequency of cold air outbreaks of 50 to 100% relative to the present in the Northern Hemisphere winter in most areas (Solomon et al. 2007, 73).

Models simulate that global mean precipitation increases with global warming. However, there are substantial spatial and seasonal variations (Meehl et al. 2007 – Figure 5). There are fewer areas stippled in the Figure for precipitation change than for temperature change, indicating more variation in the magnitude of precipitation change among the ensemble of models. Increases in precipitation at high latitudes in both seasons are very consistent across models. The increases in precipitation over the tropical oceans and in some of the monsoon regimes (e.g., South Asian monsoon in JJA, Australian monsoon in DJF)[12] are notable, and while not as consistent locally, considerable agreement is found at the broader scale in the tropics. There are widespread decreases in mid-latitude summer precipitation, except for increases in eastern Asia. Decreases in precipitation over many subtropical areas are evident in the multi-model ensemble mean, and consistency in the sign of change among the models is often high, particularly in some regions like the tropical Central American-Caribbean. There is a tendency for models to project an increase in heavy daily rainfall events in many regions, including some in which the mean rainfall is projected to decrease, as the decrease in rainfall is often attributable to a reduction in the number of rain days rather than the intensity of rain when it occurs (Solomon et al. 2007).

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[10] SRES refers to the IPCC Special Report on Emission Scenarios (Nakićenović et al. 2000). Approximate carbon dioxide equivalent concentrations corresponding to the computed radiative forcing due to anthropogenic greenhouse gases and aerosols in 2100 for the SRES B1, A1T, B2, A1B, A2 and A1FI illustrative marker scenarios are about 600, 700, 800, 850, 1250 and 1,550 ppm, respectively.

[11] Defined as seasons warmer than the 95th percentile temperature simulated for the 20th century

[12] JJA = June, July and August; DJF = December, January and February

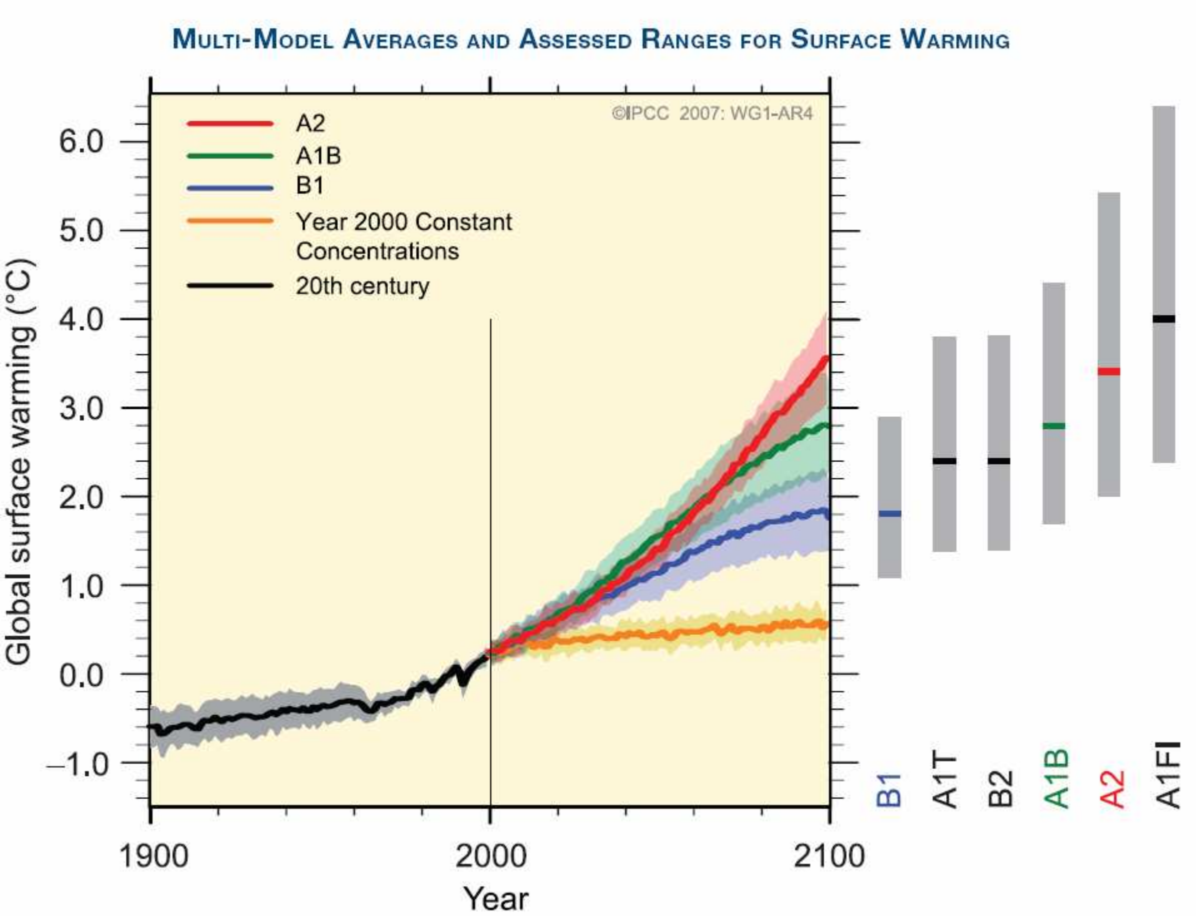


Figure 4 Multi-model global averages of projected surface warming (relative to 1980–1999) for the scenarios A2, A1B and B1 (solid lines), shown as continuations of the 20th century simulations. Shading denotes the ±1 standard deviation range of individual model annual averages. The orange line is for the experiment where concentrations were held constant at year 2000 values. The grey bars at right indicate the best estimate (solid line within each bar) and the likely range assessed for the six SRES marker scenarios. The assessment of the best estimate and likely ranges in the grey bars includes the AOGCMs in the left part of the figure, as well as results from a hierarchy of independent models and observational constraints (Source: IPCC, 2007a).

Snow cover in projected to decrease. Widespread increases in thaw depth over most permafrost regions are projected to occur (Solomon et al. 2007).

Under three SRES scenarios (A1B, A2 and B1), large parts of the Arctic Ocean are expected no longer to have year-round ice cover by the end of the 21st century, with late summer sea ice cover reducing substantially. Antarctic sea ice extent is also projected to decrease in the 21st century (Solomon et al. 2007).

In a warmer future climate, the numbers of intense hurricanes are projected to increase with a possibility of a decrease in the number of relatively weak hurricanes. Tropical cyclones are projected to have increased peak wind intensities and increased mean and peak precipitation intensities. However, the total number of tropical cyclones globally is projected to decrease (Solomon et al. 2007).

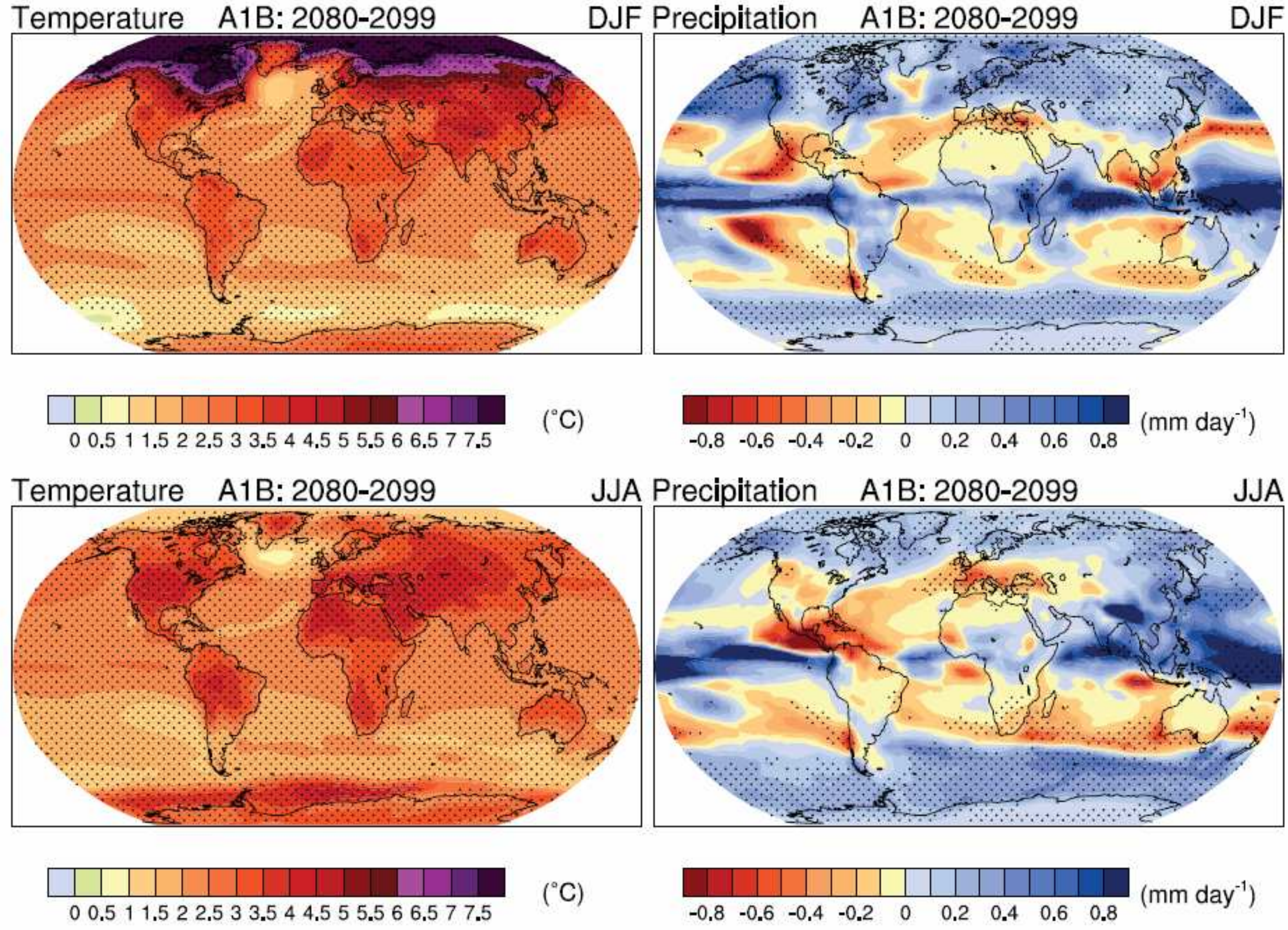


Figure 5 Multi-model mean changes in surface air temperature (°C, left) and precipitation (mm day–1, right) for boreal winter (DJF, top) and summer (JJA, bottom). Changes are given for the SRES A1B scenario, for the period 2080 to 2099 relative to 1980 to 1999. Stippling denotes areas where the magnitude of the multi-model ensemble mean exceeds the inter-model standard deviation. (Source: Meehl et al. 2007)

The range of projected globally-averaged sea level rise at the end of the 21st century (2090-2099), relative to 1980-1999 across the six SRES marker scenarios is 0.18 - 0.59 m (Solomon et al. 2007). Thermal expansion contributes 70 to 75% to the best estimate for each scenario. In all the SRES marker scenarios except B1, the average rate of sea level rise during the 21st century very likely exceeds the 1961–2003 average rate (1.8 ± 0.5 mm yr^{-1}).

Glaciers, ice caps and the Greenland ice sheet are projected to lose mass in the 21st century because increased melting will exceed increased snowfall. The ice sheets of Greenland and Antarctica have the potential to make the largest contribution to sea-level rise, but they are also the greatest source of uncertainty. However, if the recently observed increases in ice discharge rates from the Greenland and Antarctic ice sheets were to increase linearly with global average temperature change, sea level would rise 10-25% more than the estimates (Solomon et al. 2007; UNEP 2007).

4.2. **Europe**

Projected climate change in Europe

Annual mean temperatures in Europe are likely to increase more than the global mean. The warming in northern Europe is likely to be largest in winter. In the Mediterranean area, warming is likely to be largest in summer (Figure 6). The lowest winter temperatures are likely to increase more than average winter temperatures in northern Europe, and the highest summer temperatures are likely to increase more than average summer temperature in southern and central Europe. In this century, warming is projected to continue at a rate somewhat greater than its global mean. Under the A1B scenario, the simulated area and annual mean warming form 1980-1999 to 2080-2099 varies from 2.3º C to 5.3 º C in North Europe, and from 2.2º C to 5.1º C in South Europe. Along with the overall warming and changes in variability, heat waves are very likely to increase in frequency, intensity and duration in Europe. The intensity of extreme temperatures increases more rapidly than the intensity of more moderate temperatures over the continental interior. The number of frost days in very likely to decrease in Europe (Christensen et al. 2007, 872-873; Beniston et al 2007, 92)

Annual precipitation is very likely to increase in most of northern Europe and decrease in most of the Mediterranean area. In central Europe, precipitation is likely to increase in winter but decrease in summer. Extremes of daily precipitation are very likely to increase in northern Europe, while the annual number of precipitation days is very likely to decrease in the Mediterranean area. The risk of summer drought is likely to increase in central Europe and in the Mediterranean area. The annual area mean change in precipitation projected for 1980-1999 to 2080-2099 under the A1B scenario varies from 0 to 16% in northern Europe and from -4 to -27% in southern Europe. The largest increases in northern and central Europe are projected to occur in winter. In southern Europe, the largest decrease in precipitation occurs in summer, but the area mean precipitation in the other seasons is projected to decrease too. High extremes of precipitation are very likely to increase in magnitude and frequency in northern and central Europe. In the Mediterranean area and in central Europe in summer, extreme short-term precipitation events may either increase due to increased water vapour content in a warmer atmosphere or decrease due to a decreased number of precipitation days. The duration of the snow season is very likely to shorten in all of Europe, and snow depth is likely to decrease in most of Europe (Christensen et al. 2007, 872-873, Beniston et al. 2007, 92).

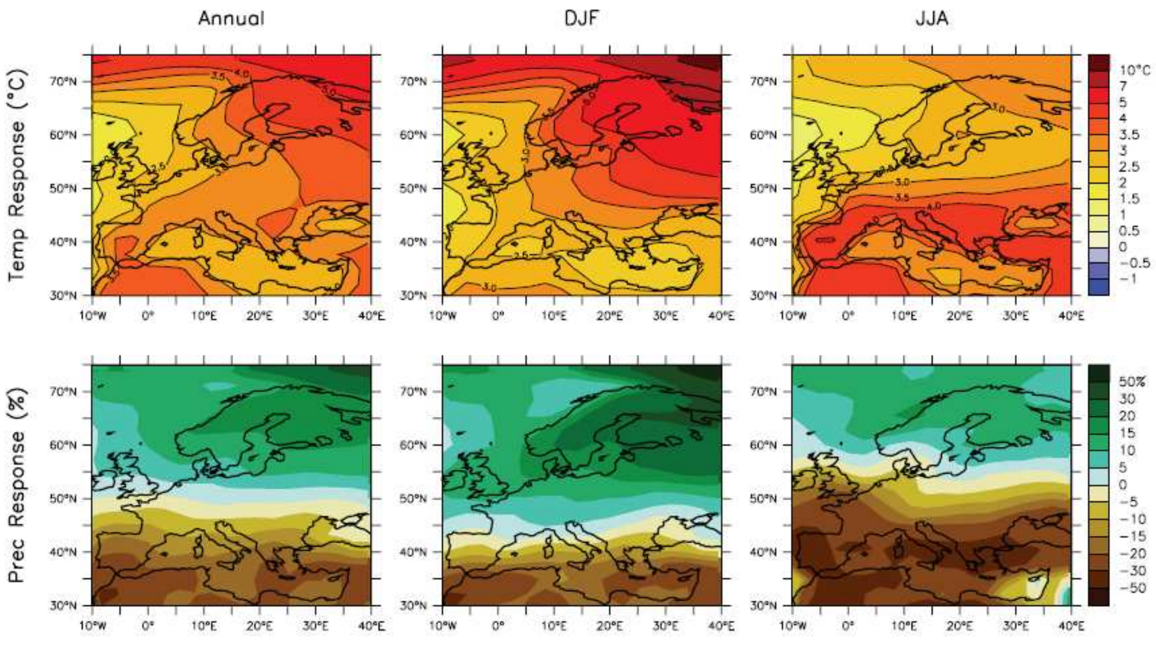


Figure 6 Temperature and precipitation changes over Europe from multi-model A1B simulations. Top row: annual mean, DJF and JJA temperature change between 1980-1999 and 2090-2099, averaged over 21 models. Bottom row: same as top, but for fractional change in precipitation.

Confidence in future changes in windiness in Europe remains relatively low. Extreme wind speeds could increase in Europe between latitudes 45º and 55º N, except over and south of the Alps, and winds are expected to become more north-westerly. These changes are associated with reductions in mean sea-level pressure, which are projected to generate more North Sea storms, leading to increases in storm surges along the North Sea coast. The northward shift in cyclone activity tends to reduce windiness in the Mediterranean area (Christensen et al. 2007, 877-878; Beniston et al. 2007, 92).

Key current climate related vulnerabilities and future risks and vulnerabilities in Europe are presented in Table 1 and Figure 7, below. More projected impacts of climate change in Europe for different sectors are presented in Annex 1, Table A 1.

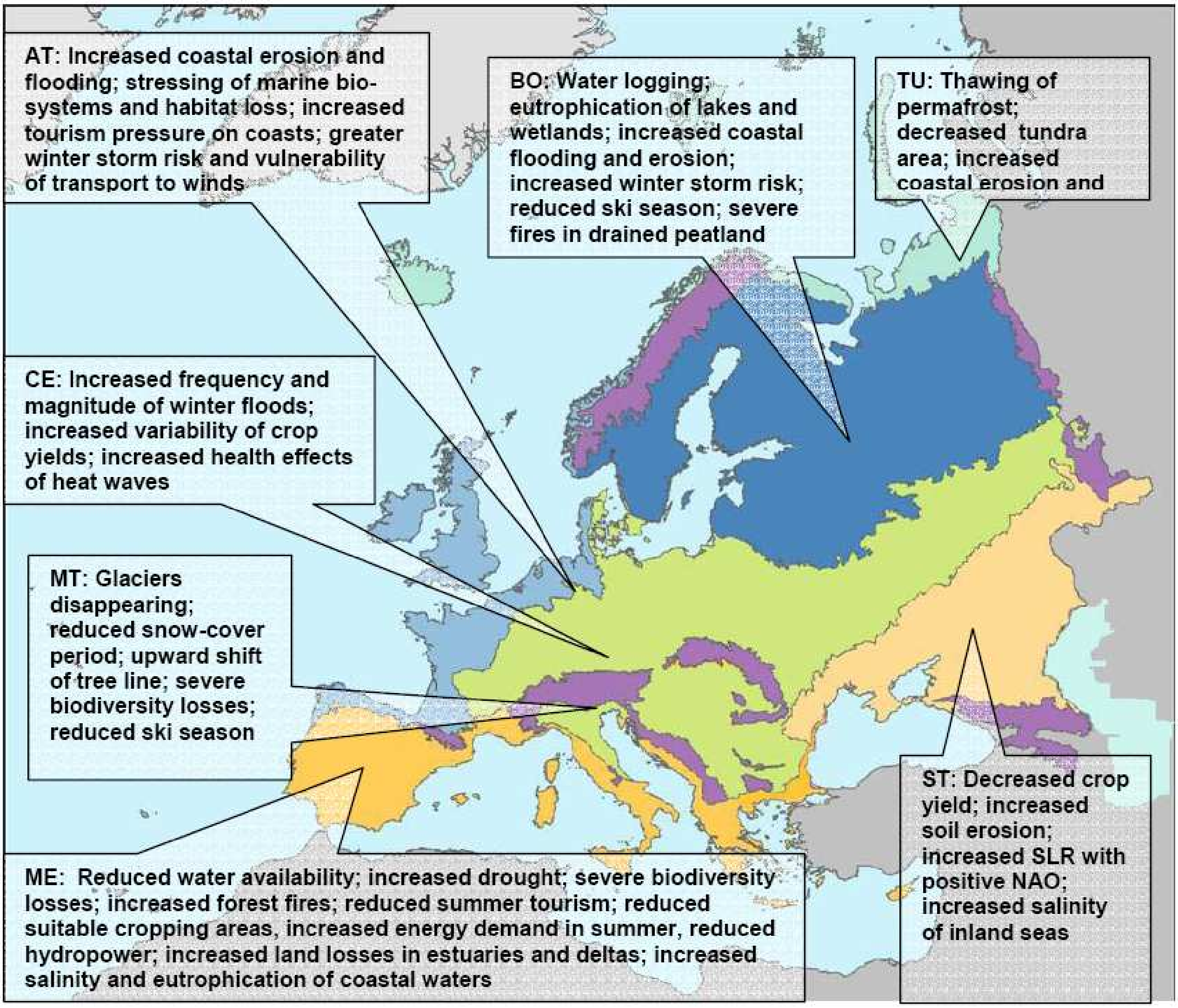


Figure 7 Key vulnerabilities of European systems and sectors to climate change during the 21st century for the main biogeographic regions of Europe – TU: Tundra, pale turquoise. BO: Boreal, dark blue. AT: Atlantic, light blue. CE: Central, green; includes the Pannonian Region. MT: Mountains, purple. ME: Mediterranean, orange; includes the Black Sea region. ST: Steppe, cream. SLR: sea-level rise. NAO: North Atlantic Oscillation. (Source: Alcamo et al. 2007)

Table 1 Risks and vulnerabilities under a changing climate in Europe.

Current climate related vulnerabilities

Europe has seen an increase in floods, heat waves and forest fires in recent years. Examples include: Floods in central Europe; drought of River Po in 2007; forest fires in Portugal and Spain in 2003 and 2005, and in Greece in 2007; the heat wave in 2003. Eight out of nine glaciated regions in Europe show significant retreat of glaciers in the past century. In the Arctic north of Europe, warmer air and water have caused melting of sea ice, the current rate of shrinkage is estimated at 8% per decade

Future vulnerabilities and risks

The Mediterranean is probably the region in Europe most vulnerable to climate change. Much of the region's biodiversity is already close to its climatic limit. Even small changes in temperature and rainfall could have severe consequences for some species. Increased wild fire risk is also a serious threat.

The Alps would lose about 80% of their glacier cover if summer air temperatures rise by 3ºC. A precipitation increase of 25% for each 1ºC would be needed to offset the glacial loss. Changes in glaciers can lead to avalanches and floods, which would pose danger in the densely populated mountain areas. The shrinking or vanishing of mountain glaciers is likely to cause meltwater streams to dry during hot and dry summers. Earlier snowmelt and reduced snowcover could affect river flows negatively, increase water temperatures, lower ground water levels and decrease soil humidity. The number of naturally snow-reliable ski areas in the Alps would drop to 500 (609 currently) under 1 °C, to 404 under 2 °C, and to 202 under a 4 °C warming. Germany is most sensitive to climate change of the Alpine countries; Switzerland the least sensitive. Low-lying ski areas are also considerably more vulnerable than areas with high altitudinal range.

Water stress in Europe is expected to increase, especially over central and southern Europe. The percentage area under high water stress is likely to increase from 19% today to 35% by the 2070s, and the additional number of people affected by the 2070s is expected to be between 16 millions and 44 millions. In the affected regions, summer flows may be reduced by up to 80%. Hydropower potential by the 2070s is expected to decline on average in Europe by 6%, but by 20-50% around the Mediterranean.

Extreme weather events – heat waves, heavy precipitation events and winter storms - are expected to increase. Climate change is expected to lead to more frequent and intense north westerly winter storms in Europe. Winter floods are likely to increase in maritime regions and flash floods are likely to increase throughout Europe. By the end of the century, coastal flooding related to increasing storminess and sea-level rise is likely to threaten up to 1.6 million additional people annually. Warmer, drier conditions will lead to more frequent and prolonged droughts, and to a longer fire season and increased wild fire risk, particularly in the Mediterranean region and on drained peatlands in central Europe.

Europe’s natural ecosystems and biodiversity will be substantially affected by climate change. Sea-level rise is likely to cause a loss of up to 20% of coastal wetlands. Many permafrost areas in the Arctic are projected to disappear. Recruitment and production of marine fisheries in the North Atlantic are likely to increase. A large percentage of the European flora is likely to become vulnerable, endangered, or committed to extinction by the end of this century.

Without adaptive measures, risks to health due to more frequent heat waves, particularly in central and southern Europe, flooding, and greater exposure to vector- and food-borne diseases are anticipated to increase. Some impacts may be positive, as in reduced risk of extreme cold events because of increasing winter temperatures. However, on balance, health risks are very likely to increase.

Crop suitability is likely to change throughout Europe, and crop productivity (all other factors remaining unchanged) is likely to increase in northern Europe, and decrease along the Mediterranean and in south-eastern Europe. Forests are projected to expand in the North and retreat in the South. Forest productivity and total biomass is likely to increase in the North and decrease in central Europe, while tree mortality is likely to accelerate in the South. Differences in water availability between regions are anticipated to become sharper.

Key (policy) questions

Mitigation policies, EU regulations and implications to Finnish policymaking
Changes in tourism areas (The Alps and Mediterranean) and seasons
Impacts on agricultural production
Demand for bioenergy

Sources: EEA 2007, 13-15; EEA 2005, 64-65, 198; Koppe et al 2004; UNEP 2007, 122, 129; ACIA 2005; Alcamo et al. 2007; OECD 2007; Beniston et al. 2007, 91; Firth et al. 2005, 23; Swiss Re 2006

4.3. North America

Projected climate change in North America

All of North America is very likely to warm during this century, and the annual mean warming is likely to exceed the global mean warming in most areas (Figure 8). In northern regions, warming is likely to be largest in winter. In the southwest USA, warming is likely to be largest in summer. The lowest winter temperatures are likely to increase more than the average winter temperatures in northern North America. The highest summer temperatures are likely to increase more than the average summer temperature in the southwest USA (Christensen et al. 2007, 887). The largest warming is projected to occur in winter over northern parts of Alaska and Canada, reaching 10ºC in the northernmost parts by 2100, due to the positive feedback from a reduced period of snow cover. On an annual mean basis, projected warming varies from 2ºC to 3ºC along the western, southern and eastern continental edges up to more than 5ºC in the northern region for 2001 to 2100 (A1B, A2 and B1 scenarios). In summer, mean projected warming ranges between 3-5ºC over most of the continent with smaller values near the coasts. In winter, the northern part of the eastern region is projected to warm most while coastal areas are projected to warm only 2-3ºC (Christensen et al. 2007, 887, 889).

Annual mean precipitation is projected to increase in the north and decrease in the south of North America. Annual mean precipitation is very likely to increase in Canada and the northeast USA, and likely to decrease in the southwest USA. In southern Canada, precipitation is likely to increase in winter and spring, but decrease in summer. Annual mean precipitation in the north is projected to increase up to 20%, the projected increase reaches as much as +30% in winter. Projected increases in annual precipitation are partially offset by increases in evaporation; therefore regions in central North America may experience net surface drying as a result (Christensen et al. 2007, 887, 890).

Snow season length and snow depth are very likely to decrease in most of North America, except in the northernmost part of Canada, where maximum snow depth is likely to increase. Studies point to a decline in winter snowpack and hastening of the onset of snowmelt caused by regional warming in western USA (Christensen et al. 2007, 887, 891).

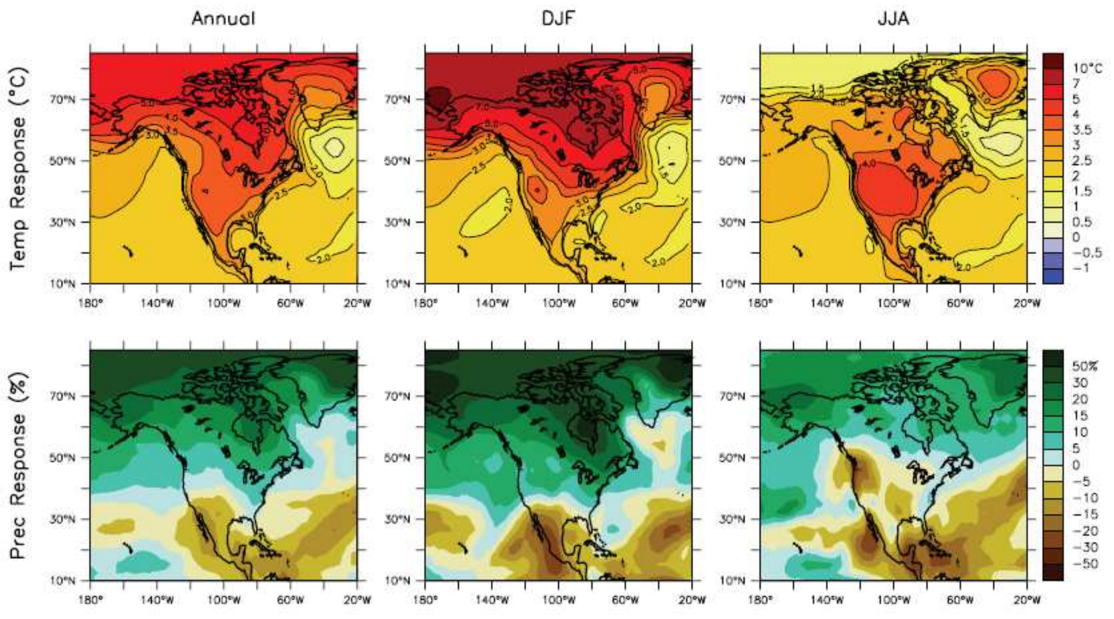


Figure 8 Temperature and precipitation changes over North America from multi-model A1B simulations. Top row: annual mean, DJF and JJA temperature change between 1980-1999 and 2080-2099, averaged over 21 models. Bottom row: same as top, but for fractional change in precipitation (Christensen et al. 2007, 890).

Projected impacts in North America

Key current climate related vulnerabilities and future risks and vulnerabilities in North America are presented in Table 2. More projected impacts of climate change in North America for different sectors are presented in Annex 1, Table A 2.

Table 2 Risks and vulnerabilities under a changing climate in North America.

Current climate related vulnerabilities
Extreme weather events have caused locally severe damages (hurricanes and other storms, floods, droughts and wild fires). Economic damages from extreme weather events have increased dramatically
Many coastal areas are potentially exposed to storm surge flooding, such as the New Orleans and Richmond regions.
Warming of the permafrost has been observed in parts of the Alaskan Arctic and north western Canada and damages have occurred in some locations to houses, infrastructure and forests. Erosion rates have increased along the arctic coasts over the past 30 years.
Future vulnerabilities and risks
Rising temperatures will diminish snowpack and increase evaporation, affecting seasonal availability of water. Heavily utilised water systems in western United States and Canada will be especially vulnerable to the impacts of climate change
Sea level rise will exacerbate the impacts of progressive inundation, storm surges and coastal erosion.
Hurricanes could increase in intensity because of global warming.
In agriculture, crops that are already close to their climatic thresholds, will be most vulnerable (such as wine in California)
Thawing of permafrost will affect foundations, pipelines, road and railway embankments.
Increased risks to human heath in urban areas due to combined impacts of urban heat island effect, air pollution and maladapted urban form and infrastructure. Increased risk of severe heat waves and adverse health effects especially in cities
Wild fire and insect outbreaks are likely to increase and intensify in a warmer climate with drier soils and longer growing seasons.
Key (policy) questions
Mitigation and climate policy Possible changes in major agricultural production areas
Sources: Field et al 2007, 622-623; UNEP 2007, 184-187; ACIA 2005, 911, 921; EPA 2007 http://www.epa.gov/climatechange/index.html; Emanuel 2005, 688; Pielke 2005; Landsea 2005; Webster et al. 2005, 1846

4.4. Latin America

Projected climate change in Latin America

All of Central and Southern America is very likely to warm during this century. The annual mean warming is likely to be similar to the global mean warming in South America but larger than the global mean warming in the rest of the area (Figure 9). Warming is projected to be generally largest in the most continental regions, such as inner Amazonia and northern Mexico. The annual mean model simulated warming under the A1B scenario between 1980-1999 and 2080-2099 varies from 1.8º C to 5.0º C in Central America, with a median of 3.2 º C. In the Amazonian region, the projected warming for the same period is 1.8 to 5.1º C (median 3.3º C). and in southern South America 1.7 to 3.9º C (median 2.5º C) (Christensen et al. 2007, 892, 894).

Annual precipitation is likely to decrease in most of Central America, with the relatively dry boreal spring becoming drier. The median annual precipitation change for the region by the end of the 21st century is projected to be 9% (under the A1B scenario). However, there could be increased rainfall in the hurricane season in the region, because tropical storms can contribute a significant fraction of the rainfall of that season. Annual precipitation is likely to decrease in the southern Andes, with largest relative changes in summer. Precipitation is likely to increase in Tierra del Fuego during winter and in south-eastern South America during summer. It is uncertain how annual and mean rainfall will change over northern South America, including the Amazon. Median changes in model projections of area mean precipitation in Amazonia and southern South America regions are small, but these averages hide marked regional differences. The annual mean precipitation is projected to decrease over northern South America near the Caribbean coasts, as well as over large parts of northern Brazil, Chile, Ecuador and Peru, around the equator and in south-eastern South America (Christensen et al 2007, 892, 894-895).

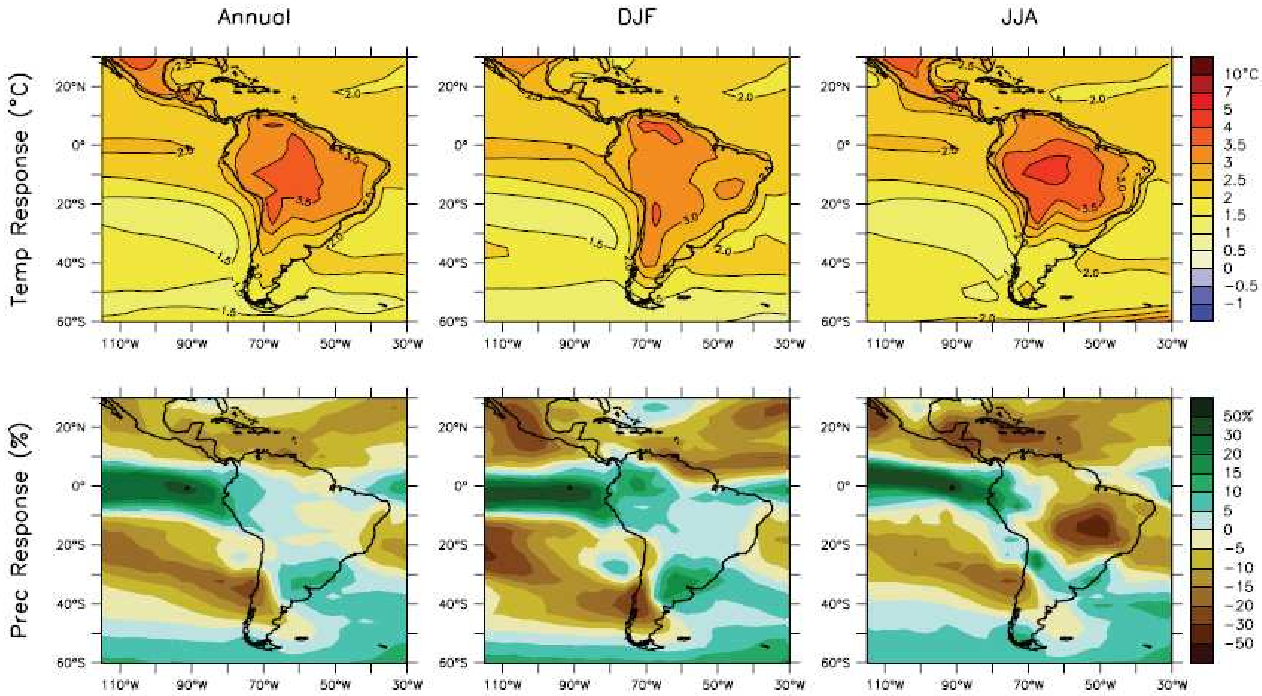


Figure 9 Temperature and precipitation changes over Central and South America from multi-model simulations under A1B scenario. Top row: annual mean, DJF and JJA temperature change between 1980 to 1999 and 2080 to 2099, averaged over 21 models. Bottom row; same as top but for fractional change in precipitation (Christensen et al. 2007, 895).

Projected impacts in Latin America

Key current climate related vulnerabilities and future risks and vulnerabilities in Latin America are presented in **Error! Reference source not found.** and Figure 10, below. More projected impacts of climate change in Latin America for different sectors are presented in Annex 1, Table A 3.

Table 3 Risks and vulnerabilities under a changing climate in Latin America.

Current vulnerabilities

Climate variability and extreme weather events (floods, hail storms, hurricanes) have seriously affected Latin America during recent years. Over the same period, land use has changed; arable land and grassland have increased at the expense of forests and wetlands. The irrigated area and the use of agrochemicals have also increased. Land degradation is a serious environmental problem in the region. It originates from processes such as erosion, loss of organic material, soil compaction, the loss of nutritive elements, chemical pollution and salinisation. It is estimated that more than 3 million km^2 of agricultural land in Latin America and the Caribbean have suffered a significant loss of productivity.

Forest cover of Latin America is decreasing and if current deforestation rates continue, Latin American forests are likely to shrink an additional 9% by 2020. In 2000, forests covered 48% of total land area. Almost half the total loss of cover in 1990-2000 was in Brazil (23 million ha, or 4.2% of the country's forests), with Mexico (6.3 million ha) and Argentina (2 million ha) far behind. Current threats to biodiversity include physical changes and habitat pollution and direct damage to organisms. Changes in habitats are caused by excessive harvesting of renewable resources (water and forests), mining, extraction of petroleum, infrastructure construction in coastal zones, forest fires, expansion of agriculture and raising livestock.

In general, Latin America and the Caribbean are rich in water resources. However, there are marked differences in water availability throughout the region. Three of its principal hydrological zones – the Gulf of Mexico, the South Brazilian Atlantic and the Paraná-Uruguay-La Plata Water basins – concentrate 40 % of the region's population in 25 % of the territory with only 10 % of total water resources. Many areas in Mesoamerica, the Andes, the Brazilian northeast and the Caribbean suffer from recurrent or chronic water shortages. The region's water reserves are reduced because of deforestation, urban expansion and excessive use due to population growth and agricultural and industrial demand. Water quality is deteriorating because of untreated sewage, excessive use of fertilisers and pesticides, and industrial, mining and energy pollution. Moreover, medium and small glaciers in central Chile and Argentina have shrunk considerably in recent decades.

Future vulnerabilities and risks

Glacier recession could severely affect the availability of water resources of millions of people in the Andean countries. Bolivia, Ecuador and Peru are at risk of water shortages, as glaciers feed rivers in those countries all year round. Changes in glaciers may also lead to hazardous conditions in the form of avalanches and floods, particularly glacier outburst floods. The Andes are also affected by hazards posed by the interaction between volcanoes and ice.

Severe water stress could be expected in some zones of Central America. Water supply and hydroelectric generation would be seriously affected in these regions. Also, the current vulnerabilities in many regions of Latin America will be increased by the joint negative effects of growing demands for water supplies for domestic use and irrigation due to an increasing population, and the expected drier conditions in many basins.

There is a high risk of forest loss in Central America and Amazonia. Wild fires are expected to increase. The tropical cloud forests are threatened by increased warming. 40% of Amazonian forests could react drastically even to a slight reduction of precipitation and the tropical vegetation, hydrology and climate system in South America could change very rapidly to another steady state, not necessarily producing gradual changes between the current and the future situation. Forests could also be replaced by ecosystems that have more resistance to multiple stresses caused by temperature increase, droughts and fires, such as tropical savannas. Under future climate change, there is a risk of significant species extinctions in many areas of tropical Latin America.

Increased heat stress and drier soils can reduce crop yields in tropical and sub-tropical areas of the continent. Salinisation and desertification of agricultural lands is also likely due to climate change. Tropical hurricanes could increase in intensity because of global warming, affecting Central and South American coastal areas.

Key policy questions

Integrating development and climate policies
Future of forest plantations, currently 9,4% of all plantations in the world are in Latin America
Biodiversity and forest loss

Sources: UNEP 2003, 40, 43, 54, 60; Magrin et al. 2007; Velarde 2004; UNEP 2007, 125-126, 141; FAO 2006 http://www.fao.org/DOCREP/009/a0470s/a0470s00.htm; Webster et al. 2005; Emanuel 2005; Landsea 2005; Arnell 2004, 26; Caceres 2004, 27; UNEP 2003, 27; UNEP 2007, 141; ECLAC 2002, Ramirez et al 2001, 27; UNMSM 2005, 27; Rowell and Moore 2000; Grasses et al. 2000; Kokot 2004 ; Barros 2005; UCC 2005; FAO 2000, 2001, 2002; WWC 2000; ECLAC/UNEP 2001

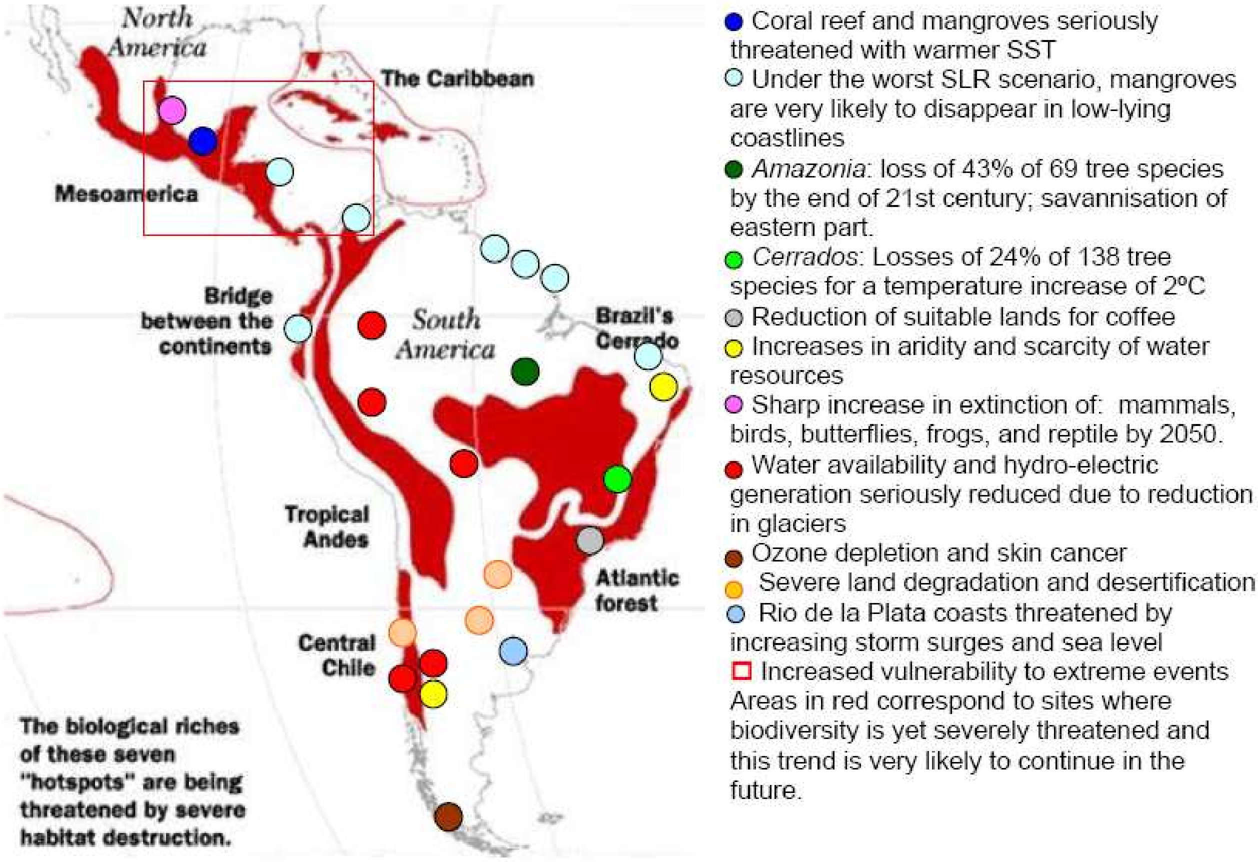


Figure 10 Key hotspots for Latin America (Magrin et al. 2007)

4.5. Africa

Projected climate change in Africa

All of Africa is very likely to warm this century during all seasons, and the warming is very likely to be larger than the global annual mean warming (Figure 11). Drier subtropical regions are expected to warm more than the moister tropics. Annual rainfall is likely to decrease in much of Mediterranean Africa and the northern Sahara, with a greater likelihood of decreasing rainfall as the Mediterranean coast is approached. Rainfall in southern Africa is likely to decrease in much of the winter rainfall region and at the western margins. There is likely to be an increase in annual mean rainfall in East Africa. It is unclear how rainfall in the Sahel, the Guinean Coast and the southern Sahara will evolve (Christensen et al. 2007, 850, 866).

The mean annual temperature is projected to increase in West Africa 3.3º C to the period 2080-2099 (compared to 1980-1999) in A1B scenario (SRES). The mean annual temperature increases 3.2 º C in East Africa, 3.4 º C in South Africa and 3.6 º C in the Saharan region for the same period and scenario. Warming is projected to be smaller (near 3º C) in equatorial and coastal areas and larger in (above 4º C) in the western Sahara. In North Africa, the largest temperature changes are projected to occur in June-August, while in southern Africa, the largest warming would occur in September-November (Christensen et al. 2007, 854, 867-868).

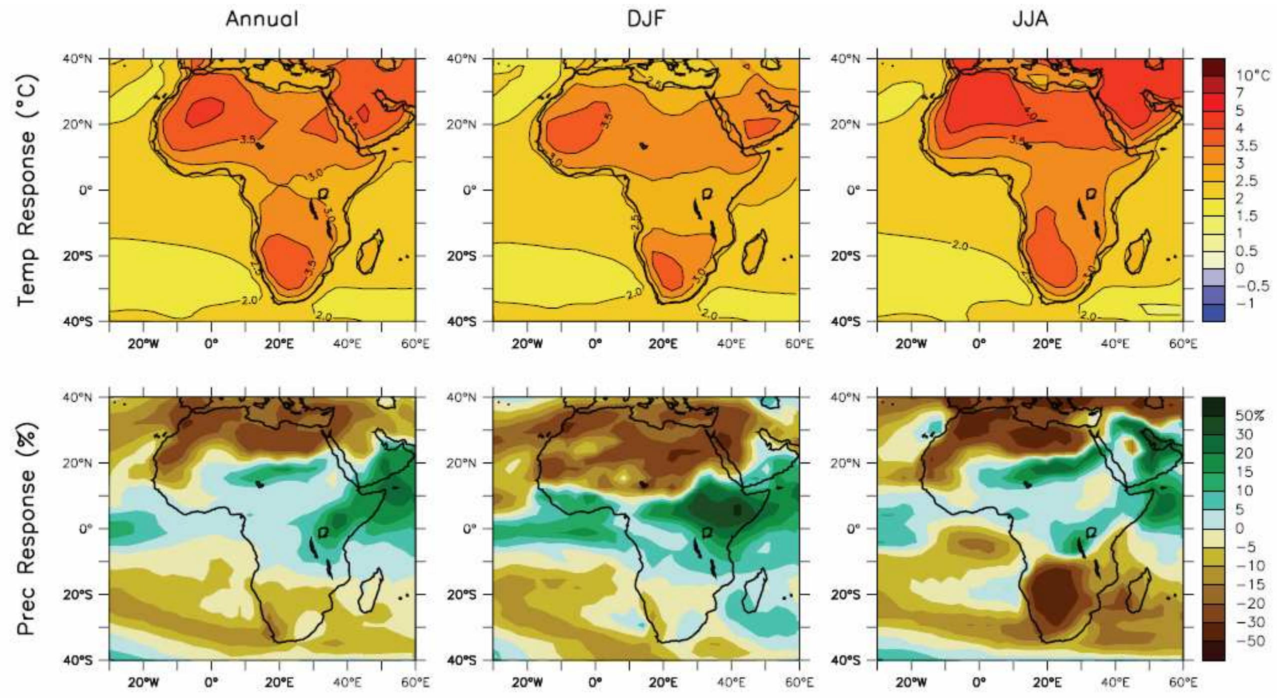


Figure 11 Temperature and precipitation changes over Africa from multi-model simulations. Top row: annual mean, DJF and JJA temperature change between 1980 to 1999 and 2080 to 2099, averaged over 21 models. Bottom row: same as top, but for fractional change in precipitation (Christensen et al. 2007, 869).

The Mediterranean region is projected to experience drying and increases in rainfall are projected for east Africa. Projected mean annual precipitation changes are: West Africa: 2 %, East Africa 7%, South Africa -4% and Saharan region -6%. Seasonal variation in precipitation change can be large. Drying is expected in much of the subtropics, especially in the extreme southwest of the continent in winter. An increase or little change in precipitation is projected in the tropics. More than half of the annual mean reduction of rainfall occurs in the spring, which can be seen as a delay in the onset of the rainy season. In East Africa, extending to the Horn of Africa, an increase in rainfall is expected. In Sahel, the modelled precipitation changes are variable and more research is needed in this region (Christensen et al. 2007, 854, 868-870).

A general increase in the intensity of high-rainfall events is expected in Africa. In regions of mean drying, there is generally a proportionally larger decrease in the number of rainy days, indicating compensation between intensity and frequency of rain. Changes in frequency and spatial distribution of tropical cyclones in the southeast coastal region of Africa remain uncertain. Extremely warm, wet and dry seasons are projected to increase by the end of this century, with all seasons becoming extremely warm and the number of extremely wet seasons increasing to 20% (compared to 5% simulated for the 20th century). In southern Africa, the frequency of extremely dry austral winters and springs increases to roughly 20%, while the frequency of extremely wet austral summers doubles (Christensen et al. 2007, 871).

Projected impacts in Africa

Key current climate related vulnerabilities and future risks and vulnerabilities in Africa are presented in Table 4 and Figure 12, below. More projected impacts of climate change in Africa for different sectors are presented in Annex 1, Table A 4.

Table 4 Risks and vulnerabilities under a changing climate in Africa.

Current vulnerabilities

Population growth is rapid in Africa. Governance is often bad, economies are dependent on agriculture and Africa's range of exports is very narrow. The highest prevalence of under-nourishment in the world (33 % of the population) is found in sub-Saharan Africa. Population growth is also counterbalancing efforts to reduce under-nourishment and results in a large increase in absolute numbers of under-nourished people. In 2005, 23 of the 36 countries facing serious food shortages throughout the world were in Africa. The causes are varied but civil strife, adverse weather and natural hazards predominate. In many of the countries, the HIV/AIDS pandemic is a major contributing factor.

In Africa around 300 million people have no access to potable water or adequate sanitation. Much of the population relies on surface water for supplies, but due to the inter-annual variability of rainfall, many are becoming reliant on groundwater. Groundwater currently represents 15% of Africa's water resources and is used by 75 % of the population, mainly in North Africa. Water availability is decreasing in Africa, and one third of the people already live in drought-prone areas, mainly in the Sahel, the Horn of Africa and Southern Africa. Water demand is increasing, affecting future access to water. By 2025, it is projected that around 480 million people in Africa will face either water scarcity or stress with a subsequent potential increase of water conflicts (almost all of the 50 river basins in Africa are trans-boundary).

Forest and woodlands occupy an estimated 650 million ha or about 22% of the land area in Africa and the region accounts for 17% of the global forest cover. Of the total area of forests and woodlands, only 5% is protected area. Forests are currently under pressure from demand for firewood and charcoal as energy sources, and from the export of forest products such as timber, nuts, fruit, gum. This has led to deforestation and degradation of African forests. Biodiversity in Africa is already under threat from a number of natural as well as human induced pressures and climate change will be an additional stressor. Threats to biodiversity include: land-use conversion due to agricultural expansion and subsequent destruction of habitat; pollution; poaching; civil war; high rates of land use change; population growth and the introduction of exotic species.

Future vulnerabilities and risks

Many vulnerable regions in Africa are likely to be adversely affected by climate change, including the mixed arid-semiarid systems in the Sahel, arid-semiarid rangeland systems in parts of eastern Africa, the Great Lakes region of eastern Africa, the coastal regions of eastern Africa, and many of the drier zones in southern Africa. Climate change is predicted to decrease and/or shift the areas of suitable climate for 81-97% of Africa's plant species

Increasing frequency of droughts and floods associated with climate variability and change could have a negative impact on the ecosystems of some areas in Africa e.g. lakes and reservoirs in the African Sahel could loose part of their storage capacity leading to a complete drying. Changing rainfall patterns could lead to soil erosion, the siltation of rivers and the deterioration of watersheds. Wetlands and wildlife are also under threat from drought in Southern Africa.

Tens of millions of additional people could be at risk of malaria by the 2080s, previously unsuitable areas for malaria could become suitable for transmission with temperature and precipitation variations. The population at risk of increased water stress in Africa is projected to be 75-250 million people by the 2020s, and 350-600 million people by the 2050s. Furthermore, large coastal cities in Africa could suffer severe damage from sea level rise.

By the 2080s, a significant decrease in suitable rain-fed land extent and production potential for cereals is estimated under climate change. The area of arid and semi-arid land in Africa could increase by 5-8% (60-90 million hectares). Wheat production is likely to disappear from Africa by the 2080s. In some countries, additional risks that could be exacerbated by climate change include greater erosion, deficiencies in yields from rain-fed agriculture of up to 50% during the 2000-2020 period, and reductions in crop growth period. In South Africa, crop net revenues will be likely to fall by as much as 90% by 2100, with small-scale farmers being the most severely affected. However, there is the possibility that adaptation could reduce these negative effects.

Key (policy) questions

Integrating development and climate policies
Food security, water issues
Health related issues
Emergency relief
Insurance, disaster management issues

Sources: Boko et al. 2007; Stern 2006, 104-105; Arnell 2005; UNESCO 2004, 8; Van Lieshout et al. 2004; FAO 2005, 117; UNEP 1999; De Wit and Jacek 2006; Brooks 2004; UNFCCC 2006; Fischer et al. 2005; Agoumi, 2003

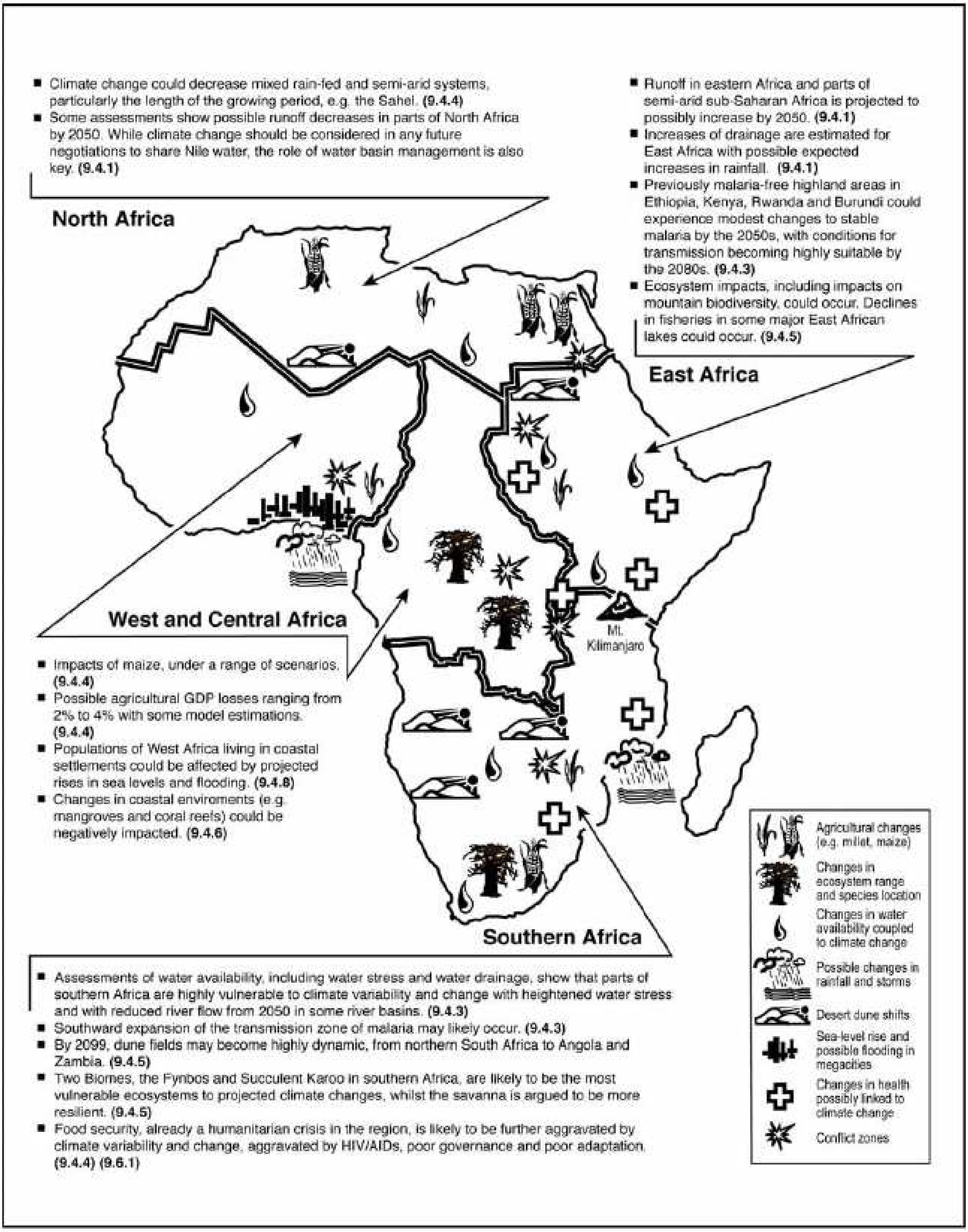


Figure 12 Future vulnerabilities in Africa (Boko et al. 2007)

4.6. **Asia**

Projected climate change in Asia

All of Asia is very likely to warm during this century (Figure 13). Warming is likely to be similar to the global mean in Southeast Asia (projected mean warming between 1980-1999 and 2080-2099 is 2.5ºC). The warming is likely to be well above the global mean in central Asia (3.7ºC), the Tibetan Plateau (3.8ºC) and northern Asia (4.3ºC), and above the global mean in East (3.3ºC) and South Asia (3.3ºC). It is very likely that summer heat waves and hot spells will be more intense, more frequent and of longer duration. It is also very likely that there will be fewer cold days in East Asia and South Asia (Christensen et al. 2007, 879, 881).

An increase in annual precipitation is projected over most of Asia during this century. The percentage increase is expected to be largest in North and East Asia. The main exception is central Asia, particularly its western parts, where reduced precipitation in the summer is projected. Sub-continental boreal winter precipitation is very likely to increase in northern Asia and the Tibetan Plateau, and likely to increase in eastern Asia and the southern parts of Southeast Asia. Summer precipitation is likely to increase in North, South, Southeast and East Asia, but decrease in central Asia. The projected decrease in mean precipitation in central Asia is accompanied by an increase in the frequency of very dry spring, summer and autumn seasons. Conversely, in winter, very high precipitation becomes more common (Christensen et al. 2007, 879, 884).

In South Asia, annual mean temperature is projected to increase 3.3ºC by the end of this century. The median warming varies seasonally from 2.7ºC in summer (JJA) to 3.6ºC in winter (DJF). Warming is likely to increase northward in the area, particularly in winter, and from sea to land (Christensen et al. 2007, 881).

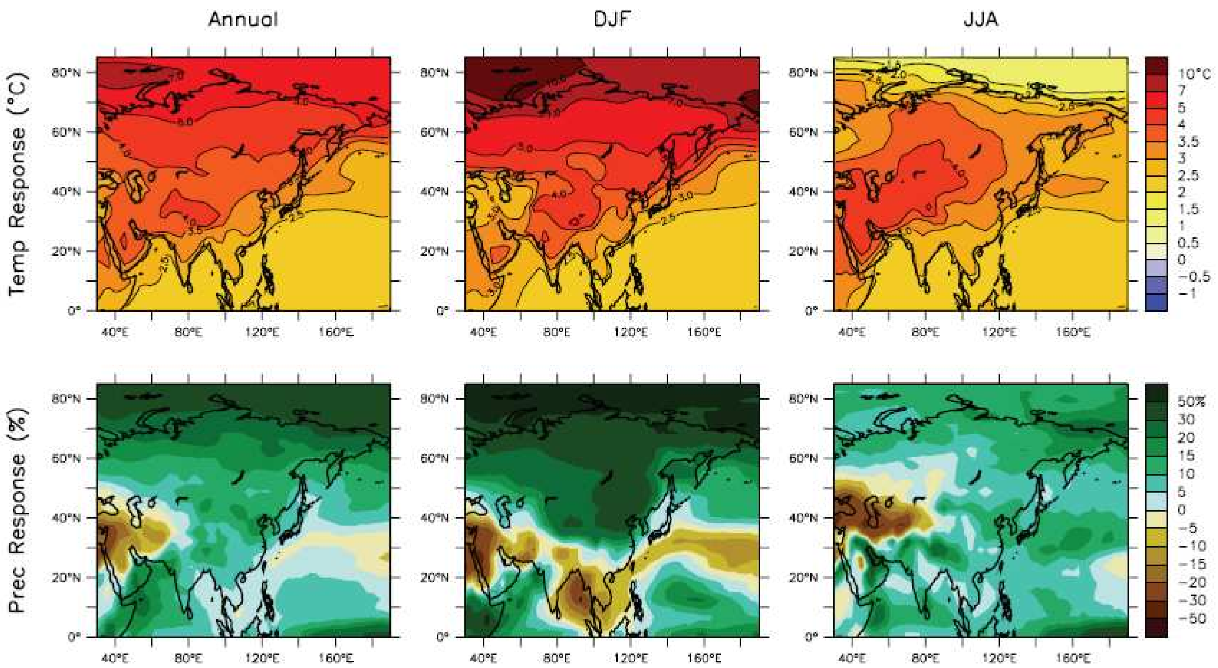


Figure 13 Temperature and precipitation changes over Asia from multi-model simulations under A1B scenario. Top row: annual mean, DJF and JJA temperature change between 1980-1999 and 2080-2099, averaged over 21 models. Bottom row: same as top, but for fractional change in precipitation. (Christensen et al. 2007, 883)

Summer precipitation is projected to increase 11% by the end of the century; winter precipitation is projected to decrease (-5% median change). Some studies indicate a general increase in the intensity of heavy rainfall events in the future, with large increases over the Arabian Sea, the tropical Indian ocean, in northern Pakistan and India, and Bangladesh and Myanmar. An overall decrease in the annual number of rainy days over a large part of South Asia is also projected by the 2050s, but with an increase in precipitation intensity (Christensen et al. 2007, 881, 884).

In East Asia, a median warming of 3.3ºC by the end of this century is projected. The warming varies seasonally from 3.0ºC in summer (JJA) to 3.6ºC in winter (DJF). The warming tends to be largest in winter, especially in the northern inland area. Daily maximum and minimum temperatures are very likely to increase in east Asia, resulting in more severe hot but less severe cold extremes (Christensen et al. 2007, 882).

An increase in the annual mean precipitation in all seasons is projected. The median change at the end of this century is +9% with little seasonal difference. Intense precipitation events are very likely to increase in East Asia. An increase in the frequency and intensity of heavy precipitation events in parts of Japan, Korea and China are projected. In northwest China, the number of rainy days is estimated to increase, while in South China the number is estimated to decrease, though days with heavy rain are estimated to increase (Christensen et al. 2007, 882, 884-885).

In Southeast Asia, the projected median warming for the region is 2.5ºC by the end of this century with little seasonal variation. The tendency for warming is significantly stronger over the interior land areas than over the surrounding coastal regions. Area-mean precipitation is projected to increase about 7% in all seasons, but projected seasonal changes vary strongly within the region. The pattern of change is broadly one of rainfall increase in the wet season and decrease in the dry season (Christensen et al. 2007, 883, 885).

A median warming of 3.7ºC is projected for Central Asia by the end of this century. Precipitation is projected to increase for DJF, but decrease in other seasons. The median change by the end of this century is -3% in the annual mean, with a 4% increase in winter (DJF) and -13% decrease in summer (JJA) which is the dry season. A median warming of 3.8ºC by the end of the 21st century is projected for Tibet. Over the Tibetan Plateau, increased precipitation is projected for all seasons (Christensen et al. 2007, 883, 887).

Projected impacts in Asia

Key current climate related vulnerabilities and future risks and vulnerabilities in Asia are presented in **Error! Reference source not found.**Table 5 and Figure 14, below. More projected impacts of climate change in Asia for different sectors are presented in Annex 1, Table A 5.

Table 5 Risks and vulnerabilities under a changing climate in Asia.

Current vulnerabilities

The state of the environment in Asia includes problems such as soil degradation, scarcity of freshwater, loss of forest cover, loss of biodiversity, and declining urban air and water quality. The rich biological resources of the Asia and Pacific region have been exploited on a massive scale. By 1985, 70-90 %of the original wildlife habitat of the countries of Asia had already been lost to agriculture, infrastructure development, deforestation, and land degradation. Forest cover is declining at a rate of approximately 1% per year (1998 estimate).

Pressure on the land in Asia is the most severe in the world. Particularly affected are the region's rural poor who are dependent on agriculture and its ancillary activities. Many countries in the region already face an acute shortage of productive land resources that can support a growing population. According to UNEP, in 1990 more than 28% of Asia's land area had some degree of land degradation. In 1998, about 39% of the region's population lived in areas prone to drought and desertification.

Safe supplies of freshwater are at risk in many countries of the region. The explosive growth in populations and economies has had the greatest impact on the region's freshwater resources. Freshwater withdrawals increased more in Asia during the 20th century than in any other part of the world, resulting in supply and water quality problems. Lack of an adequate supply of clean water is the most severe environmental, human health and economic problem in many parts of the region. Water utilization rates are expected to increase further in many parts of the region in the next quarter century as populations and economies grow. The urban population in Asia is growing significantly. By the year 2020, an additional 1.5 billion people are expected to be added to Asia's urban centres.

Future vulnerabilities and risks

Substantial decreases in cereal production potential in Asia are projected by the end of this century as a consequence of climate change. However, there are likely to be significant regional differences in yield responses. An approximate 2.5-10% decrease in crop yield is projected for parts of Asia by the 2020s and a 5 - 30% decrease by the 2050s compared with 1990 levels without CO_2 effects. An additional 49 million, 132 million and 266 million people of Asia (for an A2 scenario without carbon fertilization) could be at risk of hunger by 2020, 2050 and 2080, respectively.

Freshwater availability in Central, South, East and South-East Asia, particularly in large river basins such as the Changjiang, is likely to decrease due to climate change in combination with population growth and a rising standard of living, and could adversely affect more than a billion people in Asia by the 2050s. It is estimated that 120 million to 1.2 billion people will experience increased water stress by the 2020s; 185 - 981 million people by the 2050s.

Accelerated glacier melt is likely to cause increase in the number and severity of glacial melt-related floods, slope destabilisation and a decrease in river flows as glaciers recede. Some major rivers receive nearly 90% of their total water discharge from upper mountain catchments including glaciers and snow. Millions of people would be affected.

Projected sea-level rise is very likely to result in significant losses of coastal ecosystems and about one million people along the coasts of South and South-East Asia will likely be at risk from flooding. Sea-water intrusion due to sea-level rise and declining river runoff is likely to increase the habitat of brackish water fisheries but coastal inundation is likely to seriously affect the aquaculture industry and infrastructure particularly in heavily-populated mega-deltas. The stability of wetlands, mangroves and coral reefs around Asia is likely to be increasingly threatened. Between 24% and 30% of the coral reefs in Asia are likely to be lost during the next 10 years and 30 years, respectively. The projected future sea-level rise could also inundate low lying areas, erode beaches, and increase the salinity of rivers, bays and aquifers. Coastal regions would also be at risk of storm surges associated with more intense tropical storms.

Up to 50% of the Asia's total biodiversity is at risk due to climate change. For example, boreal forests in North Asia will be affected; taiga is likely to displace tundra, while the northward movement of the tundra will in turn decrease polar deserts. Permafrost thawing will continue over vast territories of North Asia under the projected climate change scenarios. Changes in rock and soil temperatures will result in altered strength characteristics, bearing capacity, and compressibility of the frozen rocks and soils, thaw settlement strains, frozen ground exploitability in the course of excavation and mining, and some geo-cryological processes.

Key (policy) questions

Integrating development and climate policies
Changes in agricultural production

Sources: UNEP 2007, 130-131; ADB 2001; Cruz et al. 2007; Parry et al. 1999; Rosenzweig et al. 2001; ACIA 2005

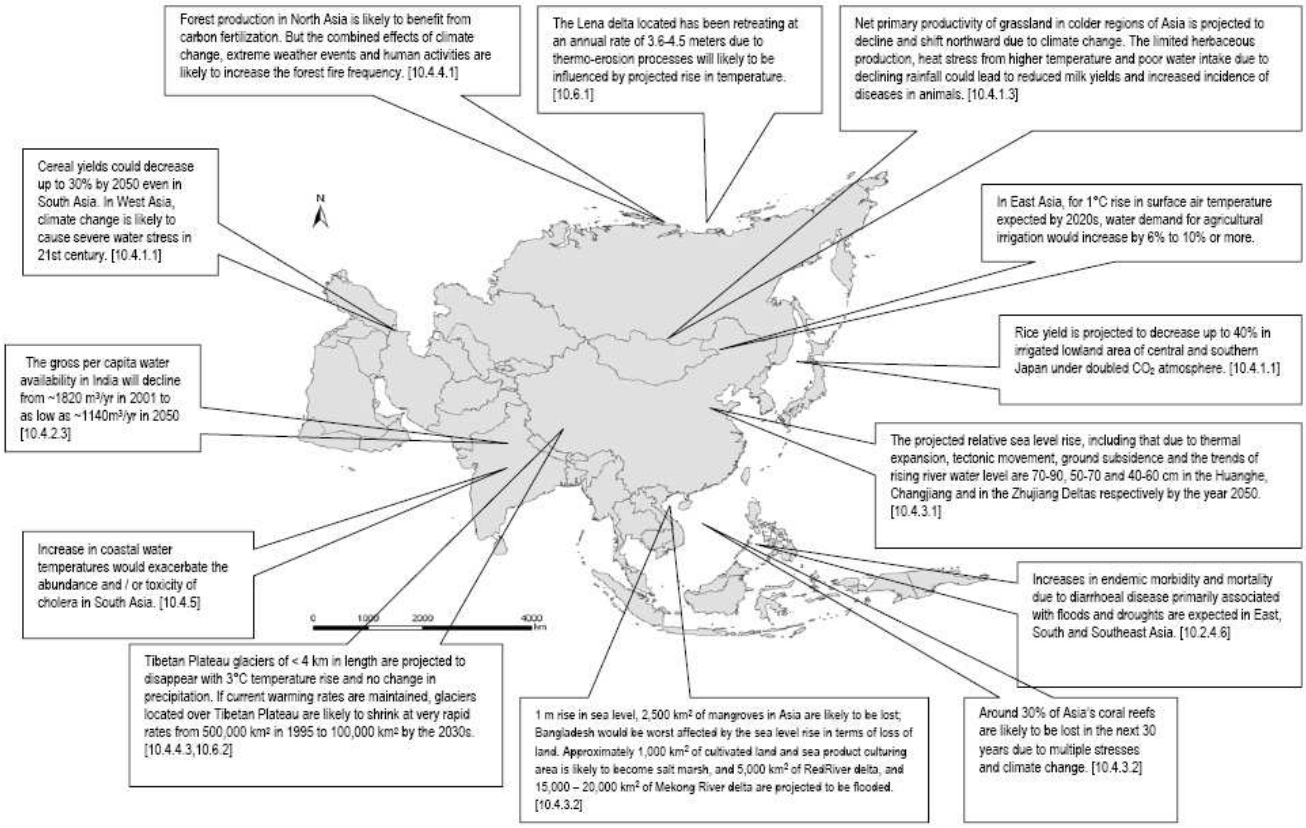


Figure 14 Hotspots of key future climate impacts and vulnerabilities in Asia (Cruz et al. 2007)

4.7. Australia and New Zealand

Projected climate change in Australia and New Zealand

All of Australia and New Zealand are very likely to warm during this century. Warming is expected to be smaller in the south, especially in winter. In southern and northern Australia, warming is projected to be larger than over the surrounding oceans, but only comparable to the global mean warming. Warming will be less in coastal regions, Tasmania and the South Island of New Zealand, and greater in central and northwest Australia. Increased frequency of extreme high daily temperatures in the region and a decreased frequency of cold extremes is very likely. The average number of days over 35ºC each summer in Melbourne could increase from 8 at present to 9-12 by 2030 and 10-20 by 2070. In Perth, the annual totals of such hot days could rise from 15 at present to 16-22 by 2030 and to 18-39 by 2070 (Christensen et al. 2007, 896, 899, 902).

Precipitation is expected to decrease in southern Australia in winter and spring and in south-western Australia in winter. Precipitation is projected to increase in the west of the South Island of New Zealand. As extremes in daily temperatures are very likely to increase, potential evaporation is likely to increase as well. Risk of drought in southern areas of Australia is therefore likely to be enhanced. However, the ENSO (El Niño-Southern Oscillation) currently influences rainfall, drought and tropical cyclone behaviour in the region significantly, and it is as yet uncertain how ENSO will behave in the future (Christensen et al. 2007, 898).

Large reductions in precipitation are projected in southern Australia in all seasons, due to poleward movement of the westerlies and embedded depressions. Reduction in precipitation also extends over land during winter when the storm track is placed furthest equatorward. The strongest effect is projected to occur in the southwest, when mean drying could be 15-20% (see Figure 13). In Australia, potential evaporation is projected to increase and the moisture balance deficit to become larger. There is a strong indication that the Australian environment will become drier under increased warming. Snow cover is expected to decline in the Australian Alps and the total alpine area with at least 30 days of snow cover to decrease 14-54% by 2020 and 30-93% by 2050 (Christensen et al. 2007, 901).

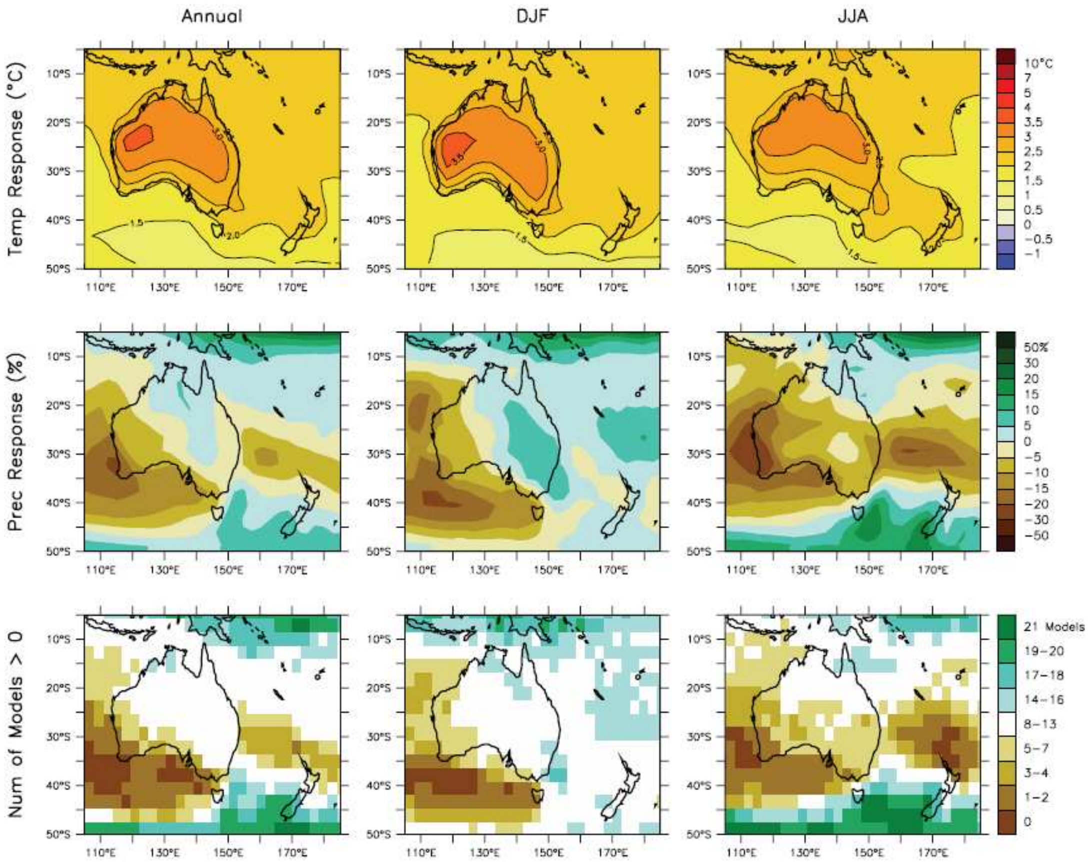


Figure 15 Temperature and precipitation changes over Asia from multi-model simulations under A1B scenario. Top row: annual mean, DJF and JJA temperature change between 1980-1999 and 2080-2099, averaged over 21 models. Bottom row: same as top, but for fractional change in precipitation (Christensen et al. 2007, 901).

Projected impacts in Australia and New Zealand

Key current climate related vulnerabilities and future risks and vulnerabilities in Australia and new Zealand are presented in Table 6**Error! Reference source not found.** and Figure 16, below.

Table 6 Risks and vulnerabilities under a changing climate in Australia and New Zealand.

Current vulnerabilities

There is clear recent evidence for increasing stresses on water supply and agriculture, changed natural ecosystems, reduced seasonal snow cover, and glacier shrinkage. Extreme events have severe impacts in both countries. In Australia, around 87% of economic damage due to natural disasters (storms, floods, cyclones, earthquakes, fires and landslides) is caused by weather-related events. Examples of recent extreme weather events in the region include droughts in Australia 1991-1995, 2002-2003, Sydney hail storm in 1999, eastern Australian heat wave in 2004, Canberra fire in 2003, New Zealand floods in 2004.

Eight mass bleaching events of coral reefs in Australia have been recorded since 1979.

Future vulnerabilities and risks

With climate change, reduced soil moisture and runoff are very likely over most of Australia and eastern New Zealand. Up to 20% more droughts (defined as the 1-in-10 year soil moisture deficit from 1974 to 2003) are simulated over most of Australia by 2030 and up to 80% more droughts by 2070 in south-western Australia. In New Zealand, severe droughts (the current 1-in-20 year soil moisture deficit) are likely to occur every 7 to 15 years by the 2030s, and every 5 to 10 years by the 2080s, in the east of both islands, and parts of Bay of Plenty and Northland. The drying of pastures in eastern New Zealand in spring is very likely to be advanced by one month, with an expansion of droughts into both spring and autumn.

An increase in fire danger in Australia is likely to be associated with a reduced interval between fires, increased fire intensity, a decrease in fire extinguishments and faster fire spread. In south-east Australia, the frequency of very high and extreme fire danger days is likely to rise 4-25%by 2020 and 15-70%by 2050. By the 2080s, 10-50% more days with very high and extreme fire danger are likely in eastern areas of New Zealand, the Bay of Plenty, Wellington and Nelson regions, with increases of up to 60% in some western areas. In both Australia and New Zealand, the fire season length is likely to be extended, with the window of opportunity for controlled burning shifting toward winter

Floods, landslides, droughts and storm surges are very likely to become more frequent and intense, and snow and frost are very likely to become less frequent. Large areas of mainland Australia and eastern New Zealand are likely to have less soil moisture, although western New Zealand is likely to receive more rain.

As a result of reduced precipitation and increased evaporation, water security problems are projected to intensify by 2030 in southern and eastern Australia and, in New Zealand, in Northland and some eastern regions.

Ongoing coastal development and population growth, in areas such as Cairns and south-east Queensland (Australia) and Northland to Bay of Plenty (New Zealand), are projected to exacerbate risks from sea-level rise and increases in the severity and frequency of storms and coastal flooding by 2050.

Significant loss of biodiversity is projected to occur by 2020 in some ecologically rich sites, including the Great Barrier Reef and Queensland Wet Tropics. Other sites at risk include Kakadu wetlands, south-west Australia, sub-Antarctic islands and alpine areas of both countries

Risks to major infrastructure are likely to increase. By 2030, design criteria for extreme events are very likely to be exceeded more frequently. Risks include failure of floodplain protection and urban drainage/sewerage, increased storm and fire damage, and more heat waves, causing more deaths and more blackouts

Production from agriculture and forestry is projected to decline by 2030 over much of southern and eastern Australia, and over parts of eastern New Zealand, due to increased drought and fire. However, in New Zealand, initial benefits to agriculture and forestry are projected in western and southern areas and close to major rivers due to a longer growing season, less frost and increased rainfall.

Key policy questions

Ecosystems and extinction risk
Water security
Coastal communities

Sources: Hennessy et al. 2007; BTE, 2001; Jones 2004; Meehl et al. 2007; Mpelasoka et al. 2007; Mullan et al. 2005; Tapper 2000; Williams et al. 2001; Cary 2002; Hennessy et al. 2006; Pearce et al. 2005;

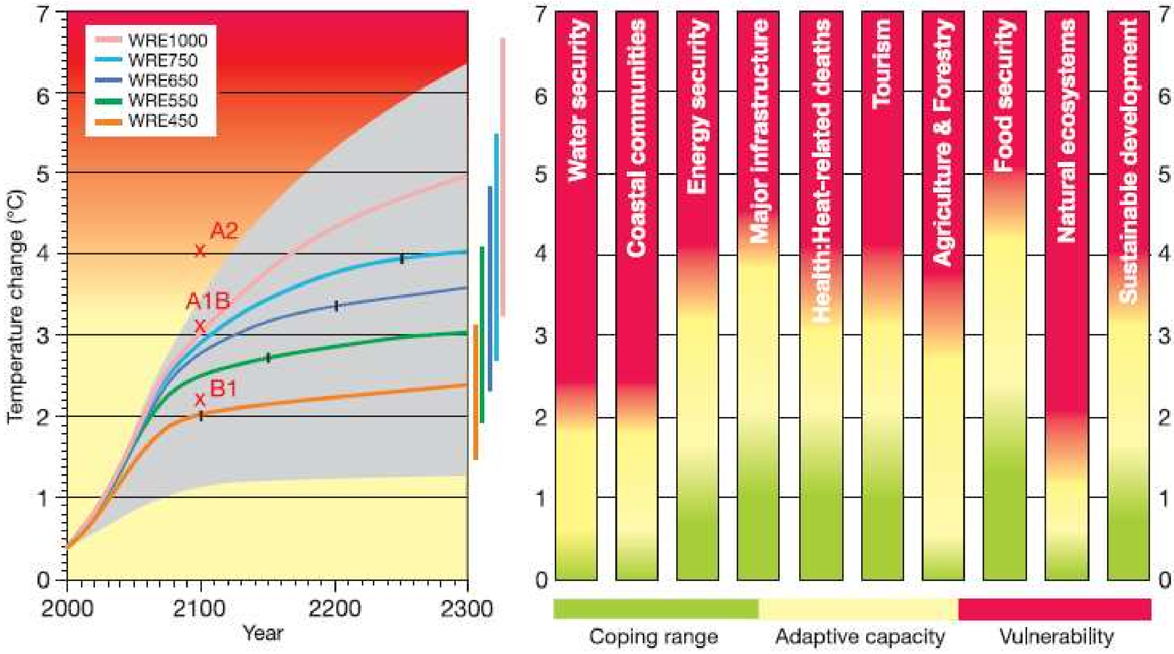


Figure 16 Vulnerability to climate change aggregated for key sectors in the Australia and New Zealand region, allowing for current coping range and adaptive capacity. In the right-hand panel, relative coping range, adaptative capacity and vulnerability are assessed. In the left hand panel, global temperature change (IPCC Third Assessment Report) is shown. The coloured curves in the left hand panel represent temperature changes associated with different CO_2 concentration stabilization levels (WRE) at 450 ppm, 550 ppm, 650 ppm, 750 ppm and 1000 ppm. The year of stabilization is shown as black dots. The shaded area indicates the range of climate sensitivity across five stabilization cases. The narrow bars show uncertainty at the year 2300 (Hennessy et al. 2007, 529).

4.8. The Arctic region

Projected climate change in the Arctic region

The Arctic is very likely to warm during this century in most areas, and the annual mean warming is very likely to exceed the global mean warming (Figure 17). Warming is projected to be largest in winter and smallest in summer. Models indicate that mean Arctic warming exceeds the global mean warming by roughly a factor of two, while the winter warming in the central Arctic is a factor of four larger than the global annual mean. By the end of this century, the projected mean warming in the Arctic ranges from 4.3ºC to 11.4ºC in winter, and from 1.2ºC to 5.3ºC in summer under the A1B scenario. Over both ocean and land, the largest warming is projected in winter and the smallest in summer. The seasonal amplitude of temperature change is however much larger over the ocean due to the presence of melting sea ice in summer, which keeps the temperatures close to freezing point (Christensen et al. 2007, 902, 904-905).

Annual Arctic precipitation is very likely to increase, with the relative increase largest in the winter and smallest in summer. The spatial pattern of projected change shows the greatest percentage increase in precipitation over the Arctic Ocean (30-40%) and smallest over the northern Atlantic (<5%). By the end of this century, the projected change in the annual mean Arctic precipitation varies from 10 to 28% under the A1B scenario (Christensen et al. 2007, 902, 906).

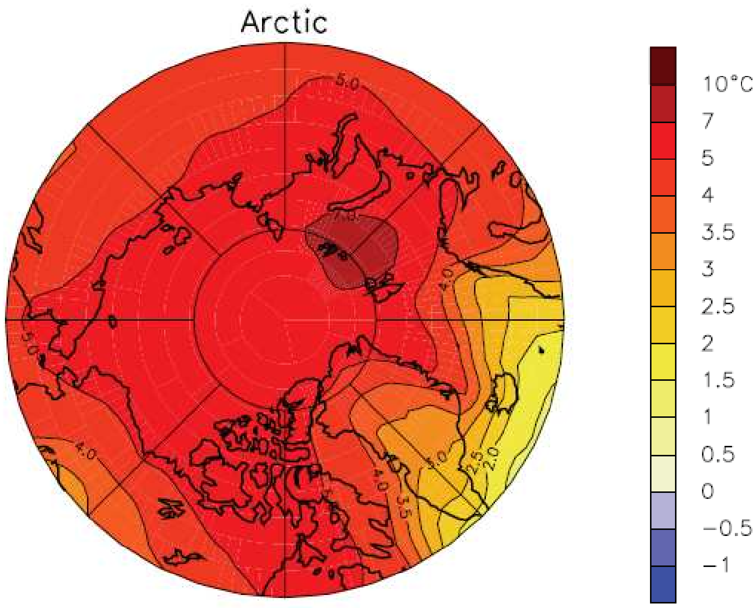


Figure 17 Projected mean annual temperature changes in the Arctic between 1980-1999 and 2080-2099 averaged over 21 models for the A1B scenario (Modified from Christensen et al. 2007, 908).

Projected impacts in the Arctic

Key current climate related vulnerabilities and future risks and vulnerabilities in the Arctic region are presented in Table 7 and Figure 18, below. More projected impacts of climate change in the Arctic for different sectors are presented in Annex 1, Table A 6.

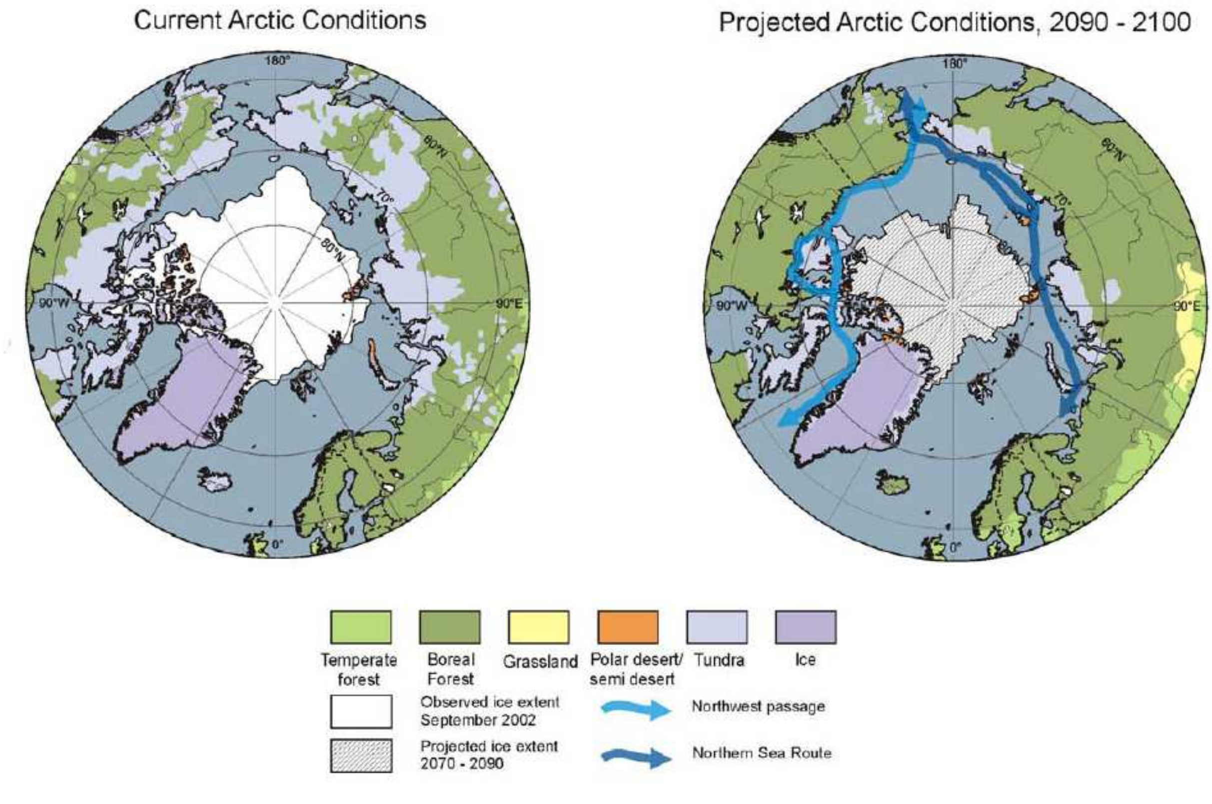


Figure 18 Present and projected vegetation and minimum sea-ice extent for Arctic and neighbouring regions.(Anisimov et al. 2007).

Arctic sea ice is very likely to decrease in extent and thickness (Figure 18). The most dramatic projected change is a mainly ice-free Arctic Ocean in late summer by 2100. In the winter, the projected decrease of sea-ice extent is 15%. In the future, there will be greater differences between seasons in sea-ice extent. In the transitional zone between high Arctic and subarctic, and in the subarctic, ice extent is projected to decline, ice seasons will be shorter and ice thinner. More frequent winter warm spells may also result in snow melting and refreezing as superimposed ice (Christensen et al. 2007, 902; UNEP 2007, 72).

The possibility of crossing critical "tipping points" in the future has been raised, manifested as periods of abrupt decrease of Arctic sea ice. These abrupt changes may result when the ice thins and the rate of retreat becomes more rapid for a given melt rate. Typically they would occur over a period of 5-10 years, during which time almost all the summer ice can disappear. Abrupt reductions early in the 21st century could result in a largely ice-free Arctic in the summer as early as 2040. However, there are still large uncertainties surrounding these processes. The transition of perennial ice to seasonal ice, which introduces new regions to seasonal sea ice cover, is another mechanism for enhanced Arctic sea-ice retreat (UNEP 2007, 73-74).

Table 7 Risks and vulnerabilities under a changing climate in the Arctic.

Current climate related vulnerabilities

The minimum (autumn) Arctic Sea ice extent has decreased during the past decades from 7.5 km^2 in 1982 to 5.6 km^2 in 2005, a reduction of 25%. The retreat of the ice cover was particularly pronounced along the Eurasian coast. At the end of summer 2005, the Northern Sea Route was completely ice-free. Snow-cover extent in the Northern Hemisphere has decreased by 5-10% since 1972. Permafrost temperatures in most of the Arctic and subarctic have increased since early 1970s. Permafrost thawing has accompanied the warming. Furthermore, earlier breakup and later freeze-up of rivers and lakes across much of the Arctic region have lengthened the ice-free season by 1-3 weeks.

Future vulnerabilities and risks

Over the 21st century, permafrost degradation is likely to occur over 10-20% of the present permafrost area. The southern limit of permafrost is likely to move northward by several hundred km. Snow cover extent is projected to decrease by about 13% by 2071-2090 (for a mean annual warming of 4ºC), with a greater decline in spring. The albedo reduction due to reduced terrestrial snow cover will be a major additional feedback on climate.

A continued decline in Arctic Sea ice extent is projected (by 25%, on average, by 2100), accompanied by thinning of the ice. In the transition zone between high Arctic and subarctic, where seasonal ice currently dominates (the Barents, Baltic, Bering and Okholtsk Seas) reduced ice extent, shorter ice seasons and thinner ice are expected. More frequent winter warm spells could also result in snow melting and refreezing as superimposed ice.

Warming is very likely to lead to replacement of tundra by forests and polar deserts by tundra. In dry areas, forests can be replaced by tundra-steppe and in areas, where thawing permafrost leads to waterlogging, by bogs and wetlands. Climate warming is very likely to lead to an increase in the total number of species in the Arctic. Specialist species adapted to the cold climate and their predators are at risk of population decline or extirpation locally. The replacement of Arctic vegetation over the long-term with more productive vegetation is likely to increase net carbon storage in the ecosystem. However, methane fluxes are also likely to increase as wetlands become warmer and as permafrost thaws.

Serious coastal erosion is already evident in some low-lying areas in the Arctic and this is projected to accelerate in the future leading to relocations of coastal communities in the Arctic. Distribution and migration patterns of fish stocks are likely to shift, and in some parts of the Arctic, fisheries may become more productive. A slow-down of the meridional overturning circulation is likely as a result of increased freshwater input from melting glaciers and precipitation.

Key (policy) questions

Role of indigenous people
Biodiversity threats
Possibility of large scale impacts (melting of permafrost, sea ice, diminishing snow cover)
Melting Arctic Sea ice and possibility of new sea routes

Sources: UNEP 2007, 68-69, 72; ACIA 2005, 996-999

5. Defining risks and vulnerabilities associated with climate change

5.1. Distributional issues of climate change impacts

The source regions that are responsible for the bulk of greenhouse gas emissions, to date, are the industrialised countries of North America and Europe. They account for around 70% of CO_2 emissions from energy production since 1850. In contrast, the regions that are likely to experience the greatest impacts of anthropogenic climate change, namely developing countries (the majority located in tropical and sub-tropical regions), account for less than one quarter of cumulative emissions. (Stern 2006, 169). Moreover, it is the poorest and most marginalised members of societies in both and rich and poor countries that are commonly the most vulnerable to the impacts of climate change(Parry et al. 2007). In this respect, the climate change issue can be regarded as a problem of inequity, with the adverse impacts falling disproportionately on the poor (Tol et al. 2004).

Mendelsohn et al. (2006) estimate that the poor countries of the world will bear the brunt of climate change damages primarily because many of them are located in warm low latitude regions. They are already struggling with current climate variability, and in some regions temperatures are already beyond the optimum for many climate sensitive economic sectors. The rich nations on the other hand are primarily located in the mid to high latitudes, with more temperate climates. Some of them may well benefit from a modest level of climate change.

Moreover, in many developing countries climate change is only one of a number of stresses that should be superimposed on current vulnerabilities. Other contributing factors to their higher vulnerability to damaging impacts include a larger proportion of the economy concentrated in climate sensitive sectors, especially agriculture, and a deficit or absence of capital and technology to enhance adaptive capacity (O'Brien et al. 2003). Many developing countries are vulnerable because of current land degradation due to land use change and desertification, declining run-off from water catchments or depleted groundwater supplies, high dependence on subsistence agriculture and the prevalence of HIV/AIDS and other diseases. Inadequate governance mechanisms and rapid population growth increase vulnerability as well.

Developing countries are also undergoing rapid urbanisation. Migrants to the cities frequently live in poor conditions on marginal land and are particularly vulnerable to climate change because of their limited access to clean water, sanitation, and food security. Many mega-cities in developing countries are situated in coastal areas and are vulnerable to sea level rise and flooding. Vulnerability is also a dynamic concept and can change over time in response to structural and economic changes and other external shocks (IDS 2006, 6; Sperling 2003; O'Brien et al. 2003, Stern 2006, 92; IPCC 2007b).

Countries, developed or developing, are not uniform in their vulnerability to climate change impacts and their capacity to adapt, and there are also distributional effects within countries. Many countries are large enough to experience differential effects within their borders. Some individuals, sectors and systems in a country or region will be less affected by climate change, or may even benefit, while other individuals, sectors and systems may suffer significant or even catastrophic losses. Poor people in general, wherever they live, may be more vulnerable to climate change and they could be burdened even more than the aggregate national numbers suggest. In most countries, there is a wide disparity of agricultural productivity across regions. In the low latitudes, the rural poor tend to live in the warmer and drier regions of each country. Further warming is likely to damage these regions more severely than more temperate zones. The poor are unlikely to have access to capital and are therefore likely to suffer larger damages and find it harder to adapt than other sections of the population.. The poor may also have more difficulty moving away from environmentally degraded areas, as their assets may be closely tied to specific pieces of property that may be of low value once climate changes. Finally, the poor cannot purchase their way out of reductions in crop productivity, and they may not have the resources to buy food (Mendelsohn et al. 2006,, IPCC 2007b).

5.2. Global sectors with high vulnerability to climate change

Water resources and agriculture/food security are among those global sectors where the impacts of climate change will be most evident. Impacts of climate change globally on these sectors can have implications for Finland as well, through the availability of agricultural products and the targeting of development or climate policies. More general implications for Finland could result from conflicts or disasters that happen elsewhere in the world and affect human well-being, security and possibly the world economy.

Water resources

In many regions of the world, there is already water stress. In 2000, of the world’s total population 20% had no appreciable natural water supply, another 65% shared low-to-moderate supplies (defined as less than 50% of global runoff) and only 15% enjoyed relative abundance (>50% of global runoff). Figure 19 illustrates where human water use (domestic, industrial and agricultural) exceeds average water supplies annually. Areas of high water overuse (highlighted in red to brown tones) tend to occur in regions that are highly dependent on irrigated agriculture, such as the Indo-Gangetic Plain in South Asia, the North China Plain and the High Plains in North America. Where water use exceeds local supplies society is dependent on infrastructure that transports water over long distances (i.e., pipelines and canals) or on groundwater extraction — an unsustainable practice over the long-term. There are also seasonal shortages of water, which are not reflected in Figure 19. The consequences of overuse include diminished river flow, depletion of groundwater reserves, reduction of environmental flows needed to sustain aquatic ecosystems, and potential societal conflict (United Nations 2006, 2).

Climate change will intensify the water cycle and change patterns of water availability. Projections indicate that droughts and floods will become more severe in many regions. There will be more precipitation in high latitudes and less in the dry subtropics. Climate change increases water resource stresses in the regions where runoff decreases. These regions tend to be already relatively dry. In some water-stressed parts of the world – particularly in southern and eastern Asia – climate change increases runoff, but this may not be very beneficial in practice because increases tend to come during the wet season and extra water may not be available during the dry season. Warming will be greater over land than over the oceans, and higher land surface temperatures are likely to enhance evapotranspiration leading to drier soils (Stern 2006, 62; Arnell 2004).

In many mountainous regions of the world, under higher temperatures more winter precipitation would fall as rain rather than snow. This would mean that the runoff season may shift from spring to winter. Effects on summer water resource availability could be very large even though the change in total annual runoff could be small. About one-sixth of the world's population relies on water released from snowpacks or glacier melt to maintain water supplies during the peak water demand season. Initially, water flows may increase in the spring as glaciers melt more rapidly. This could increase the risk of glacial lake outburst floods. In the long-run, however, dry season water will disappear permanently once a glacier has completely melted (Arnell 2006, 16; Stern 2006, 63).

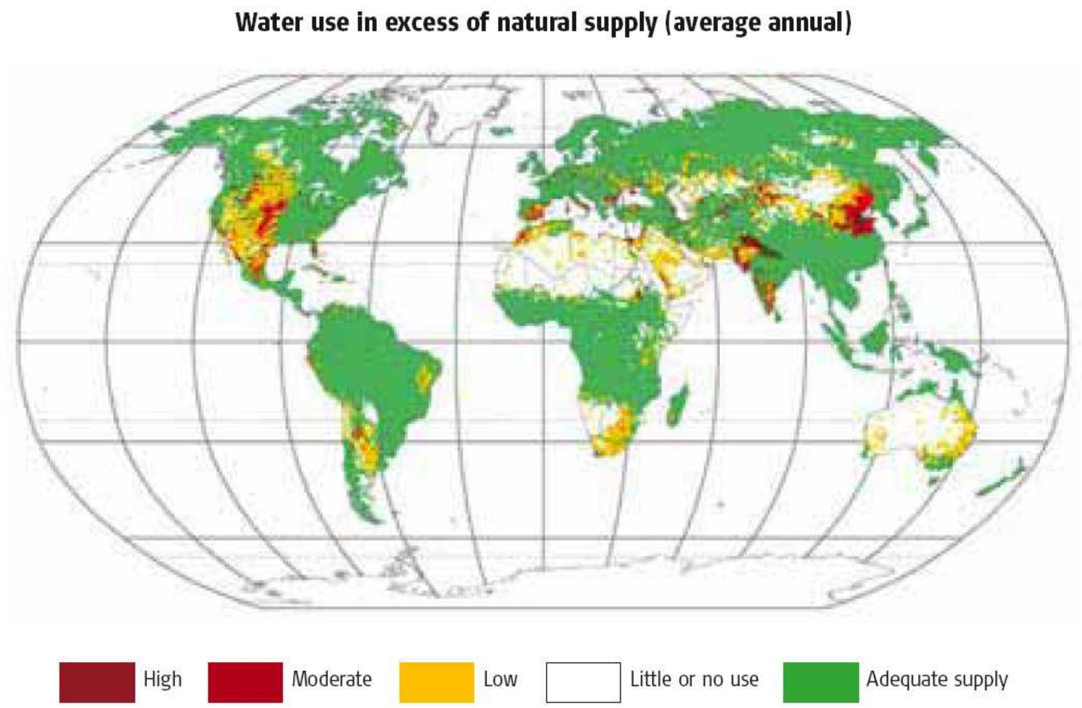


Figure 19 Areas where (current) human water use (domestic, industrial and agricultural) exceeds average water supplies annually (United Nations 2006, 18)

Food security

Food production will be particularly sensitive to climate change, because crop yields depend in large part on prevailing climate conditions (temperature and rainfall patterns). Agriculture currently accounts for 24% of world output, employs 22% of the global population and occupies 40% of the land area. 75% of the poorest people in the world live in rural areas and rely on agriculture for their livelihoods.

Low levels of warming in mid to high latitudes could improve the conditions for crop growth by extending the growing season and/or opening up new areas for agriculture. Further warming will have increasingly negative impacts though as damaging temperature thresholds are reached more often and water shortages limit growth in some regions. In contrast, even modest warming is expected to reduce crop yields in the tropics and subtropics. There crops are already close to critical temperature thresholds and many countries have limited capacity to make economy-wide adjustments to farming patterns. Many of the effects of climate change on agriculture will depend on the degree of adaptation, which will be determined by income levels, market structure, and farming type, such as rain-fed or irrigated. Adaptation potential in general is greater in more developed economies in the north. This, together with more favourable effects of climate change on yield potential will aggravate inequalities in development potential in the world (Parry et al. 2005, 2137; Stern 2006, 67-68).

Climate change can increase the risk of hunger generally and particularly in southern Asia and Africa. The food supply system is complex, however, and moderate increases in air temperature do not necessarily lead to shortfalls in cereals at global level. Regional differences in crop production are likely to grow stronger over time, however, leading to significant polarisation effects and substantial increases in risk of hunger in poorer countries of the world (Parry et al. 2004, 66).

5.3. Dangerous climate change

The objective of the UNFCCC is the "stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner". The concept of "dangerous anthropogenic interference" leaves a wide scope for interpretation (e.g. Swart and Vellinga 1995, Parry et al. 1996) and ultimately its determination cannot be based on scientific arguments alone, but involves other judgements informed by the state of scientific knowledge (Schneider et al. 2007).

Key vulnerabilities may be linked to systemic thresholds where non-linear processes cause a system to shift from one major state to another. These are often referred to as "abrupt changes"[13] or "singularities". Other key vulnerabilities can be associated with "normative thresholds", defined by stakeholders or decision-makers, such as a level of change where a magnitude of impact is incurred that is no longer considered acceptable or where the frequency of impacts of extreme weather events exceeds tolerable levels. These latter vulnerabilities can be explored by examining impacts under incremental levels of climate change. Both these and abrupt changes are described in more detail below.

Impacts of incremental climate change

The IPCC has illustrated some estimated impacts of climate change during the 21st century for increasing increments of global mean temperature change by sector (Table 8) and by world region (Table 9). Numbers of people affected are based on alternative scenarios of gross domestic product (GDP) and population, and estimates do not account for adaptation. To provide an impression of the projected rate of warming across the SRES emissions scenarios, estimates for different time periods during the century (2020s, 2050s, 2080s and 2090s) are also shown, extracted from Figure 4 (above). Temperature changes are relative to 1980-1999. For estimates relative to 1850-1899 (early in the industrial era), add 0.5°C.

The impacts of climate change are estimated to intensify with increased amounts of warming. IPCC (2007b) estimates that for a global mean annual temperature change of 2ºC relative to 1980-1999 there will be adverse impacts to many systems including ecosystems and food production. Up 30% of species will be at risk of extinctions and there will be a tendency for cereal productivity to decrease in low latitudes. For a warming of about 4ºC, impacts get more severe. There will be significant extinctions around the globe, and productivity of all cereals decreases in low latitudes.

[13] An abrupt climate change occurs "when the climate system is forced to cross some threshold, triggering a transition to a new state at a rate determined by the climate system itself and faster than the cause" (Alley et al. 2002). In systems that contain more than one equilibrium state, transitions to structurally different states are possible. Some changes may be reversible, but others are irreversible (or effectively irreversible, such as the disappearance of an ice sheet, which will not re-appear with the return of historical climate conditions). Climate surprises usually refer to abrupt transitions or permanent or temporary transitions to a different state in parts of the climate system. Possible abrupt climate changes, climate surprises and irreversible changes in the climate system include ocean circulation changes, melting of Arctic sea ice, glaciers and ice gaps, melting and accelerated ice flow of the Greenland and Antarctic ice sheets, and irreversible and relatively rapid changes in vegetation cover (Meehl et al. 2007, 775-777).

Table 8 Examples of global impacts projected for changes in climate (and sea level and atmospheric CO_2 where relevant) associated with different amounts of increase in global average surface temperature in the 21st century. Edges of boxes and placing of text indicate the range of temperature change to which the impacts relate. Arrows between boxes indicate increasing levels of impacts between estimations. Other arrows indicate trends in impacts. All entries for water stress and flooding represent the additional impacts of climate change relative to the conditions projected across the range of SRES scenarios A1FI, A2, B1 and B2. Adaptation to climate change is not included in these estimations. For extinctions, "major" means ~40 to ~70% of assessed species. The top panel shows global temperature changes projected for the SRES scenarios for the 2020s, 2050s, 2080s and 2090s relative to 1980-1999. To express the temperature change relative to 1850-1899, add 0.5°C. Best estimates are based on atmosphere-ocean general circulation models (coloured dots). Uncertainty ranges for the 2090s are based on models, observational constraints and expert judgement. Modified from Parry et al. (2007).

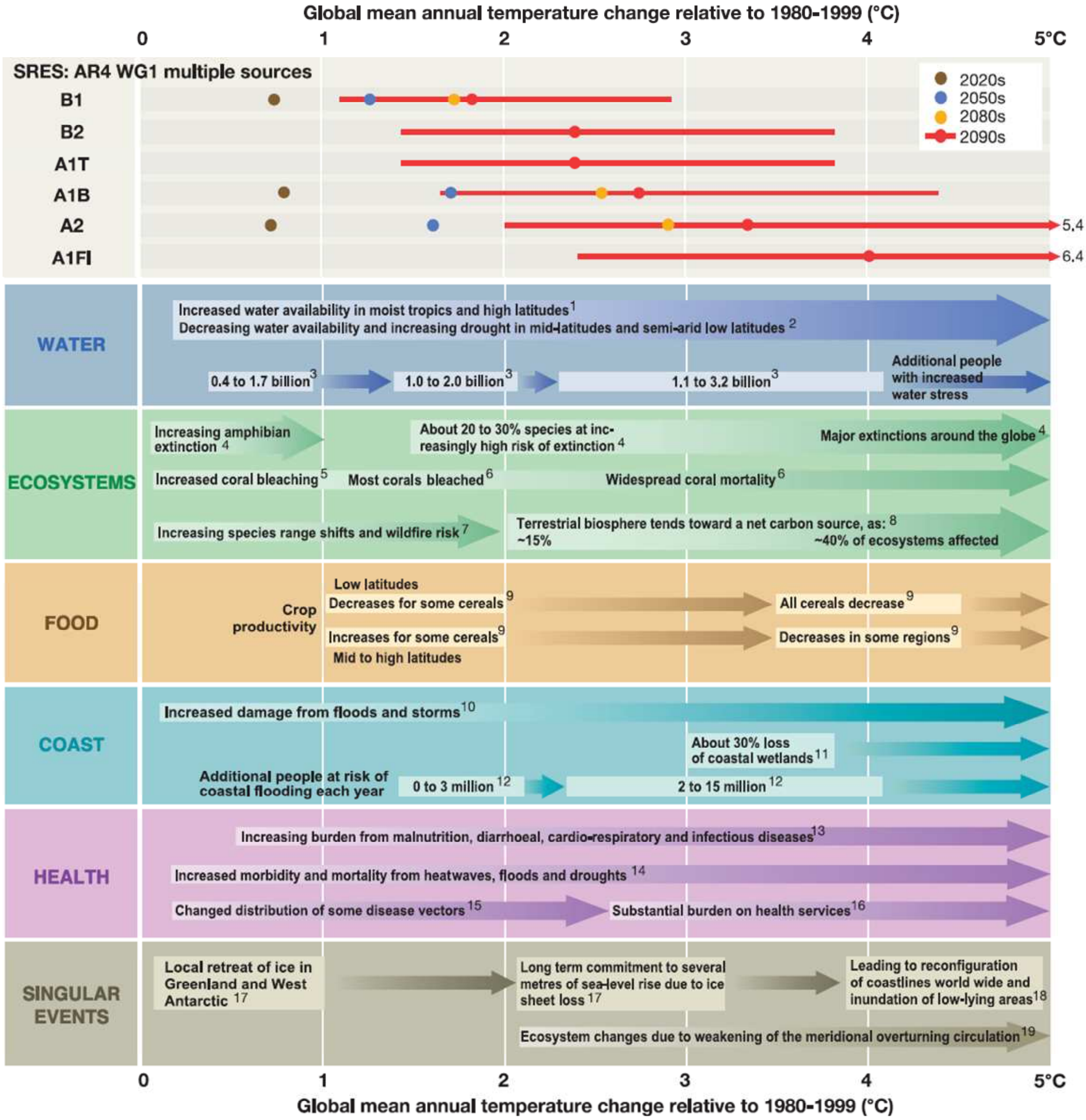
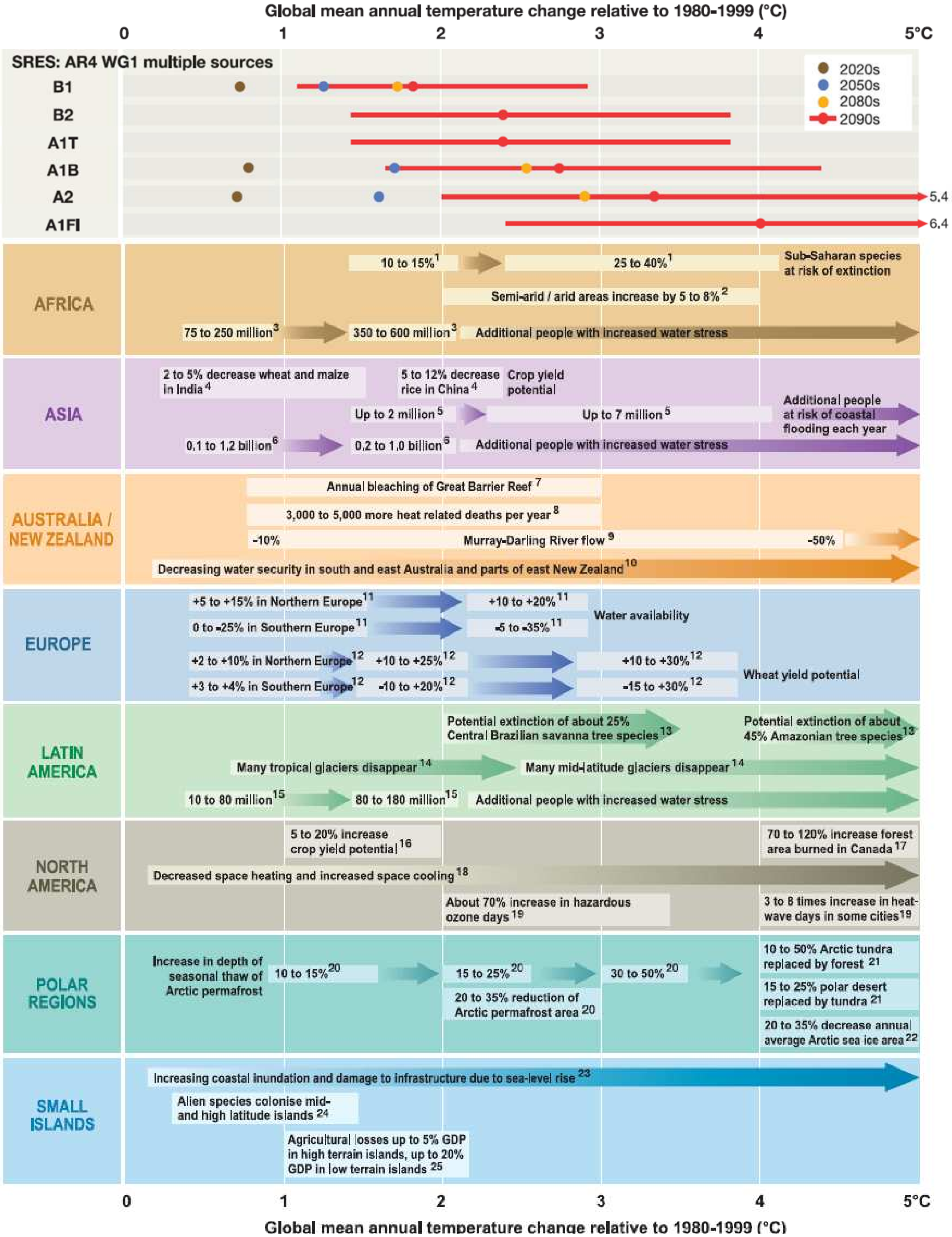


Table 9 As Table 8, **Error! Reference source not found.**but for examples of regional impacts. Modified from Parry et al. (2007).



For a warming of > 2ºC, millions more people could experience coastal flooding each year. The Stern Review (Stern 2006), measuring global warming levels relative to pre-industrial[14], projected that for a warming of only 1ºC, permafrost thawing damages buildings and roads in parts of Canada and Russia and at least 10% of land species would face extinction. Climate impacts on the environment become severe with a warming > 2ºC, with 15-40% of species facing extinction, and a high risk of extinction of Arctic species. With a warming of >3ºC, some models predict the onset of Amazon forest collapse.

With increased warming, the occurrence of extreme weather events, such as heat waves, is expected to increase. For example, regional surface warming is expected to cause the frequency, intensity and duration of heat waves to increase in Europe. By the end of this century, central Europe is projected to experience the same number of hot days as a currently experienced in southern Europe. In addition, the intensity of extreme temperatures is projected to increase more rapidly than the intensity of more moderate temperatures over the continental interior (Beniston et al. 2007, 92).

Climate change is also expected to intensify the water cycle, so that severe droughts and floods occur more often. Climate could hence become more unpredictable. For example, fluctuations in the strength of the monsoon, both year to year and within a single season, can lead to significant flooding or drought with significant impacts to the regions that are dependent on monsoon rains (Stern 2006, 58-59; IPCC 2007b).

Climate change affects also risk factors that are not climate related in a society. By altering average climate conditions and climate variability, climate change also affects underlying risk factors and the ability to cope with and recover from climate events and other natural hazards. While most impacts of climate change are exacerbations of existing threats, some impacts may be new to a region and consequently no experience in dealing with these impacts may exist in the region. Many such events may also be threshold events, or related to climate-induced spatial and temporal changes in impacts. These events include, for example, the spread of climate sensitive diseases to regions where they have not occurred before (Sperling & Szekely 2005, 8-10).

Abrupt changes – large-scale singularities

The greater the warming is, the more severe the impacts could be, particularly because there is an increased risk of triggering abrupt and large-scale changes, such as melting of the Greenland ice sheet or loss of Amazonian forest (Stern 2006, 59). The European Environment Agency identifies four types of abrupt impacts of climate change that have potentially large consequences for Europe (EEA 2005a, 68-69). They are: the potential melting of the Greenland and/or West Antarctic ice sheets, the collapse or slowing down of the North Atlantic Current, release of large amounts of methane from frozen tundra and continental shelves, and a change in how terrestrial ecosystems exchange CO_2 with the atmosphere. Table 10 presents an aggregate view of some selected key vulnerabilities resulting from different types of climate or related changes.

[14] This means that the warming would be less if measured relative to recent climate. For example, Parry et al. (2007) use an increment of 0.5°C to convert from 1850-1899 to 1980-1999 levels.

Table 10 Table of selected key vulnerabilities. Most impacts are the result of changes in climate, weather and/or sea level, not of temperature alone. In many cases climate change impacts are marginal or synergistic on top of other existing and possibly increasing stresses. Criteria for key vulnerabilities are magnitude, timing, persistence/reversibility, potential for adaptation, distributional aspects, likelihood and "importance" of the impacts. Confidence levels: *** very high, ** high, * medium, • low. Source: Parry et al. (2007).

Key systems or groups at risk	Prime criteria for 'key vulnerability'	Global average temperature change above 1990					
		0°C	1°C	2°C	3°C	4°C	5°C
Global social systems							
Food supply	Distribution, magnitude		Productivity decreases for some cereals in low latitudes ** Productivity increases for some cereals in mid/high latitudes **	Global production potential increases to around 3°C, decreases above this * **a**	Cereal productivity decreases in some mid/high latitude regions **		
Aggregate market impacts and distribution	Magnitude, distribution	Net benefits in many high latitudes; net costs in many low latitudes * **b**		Benefits decrease, while costs increase. Net global cost * **b**			
Regional system							
Small islands	Irreversibility, magnitude, distribution, low adaptive capacity	Increasing coastal inundation and damage to infrastructure due to sea-level rise **					
Indigenous, poor or isolated communities	Irreversibility, distribution, timing, low adaptive capacity	Some communities already affected ** **c**	Climate change and sea-level rise adds to other stresses **. Communities in low-lying coastal and arid areas are especially threatened ** **d**				
Global biological systems							
Terrestrial ecosystems and biodiversity	Irreversibility, magnitude, low adaptive capacity, persistence, rate of change, confidence	Many ecosystems already affected ***	*c.* 20-30% species at increasingly high risk of extinction *	Terrestrial biosphere tends toward a net carbon source **	Major extinctions around the globe **		
Marine ecosystems and biodiversity	Irreversibility, magnitude, low adaptive capacity, persistence, rate of change, confidence	Increased coral bleaching **	Most corals bleached **	Widespread coral mortality **			
Geophysical systems							
Greenland ice sheet	Magnitude, irreversibility, low adaptive capacity, confidence	Localised deglaciation (already observed due to local warming), extent would increase with temperature *** **e**		Commitment to wide-spread ** or near-total * deglaciation, 2-7 m sea-level rise[19] over centuries to millennia * **e**		Near-total deglaciation ** **e**	
Meridional Overturning Circulation	Magnitude, persistence, distribution, timing, adaptive capacity, confidence	Variations including regional weakening (already observed but no trend identified) **f**		Considerable weakening **. Commitment to large-scale and persistent change including possible cooling in northern high-latitude areas near Greenland and north-west Europe •, highly dependent on rate of climate change.			
Risks from extreme events							
Tropical cyclone intensity	Magnitude, timing, distribution	Increase in Cat. 4-5 storms */**, with impacts exacerbated by sea-level rise		Further increase in tropical cyclone intensity */**			
Drought	Magnitude, timing	Drought already increasing * **g** Increasing frequency / intensity drought in mid-latitude continental areas ** **h**		Extreme drought increasing from 1% land area to 30% (A2 scenario) * **i** Mid-latitude regions affected by poleward migration of Annular Modes seriously affected ** **j**			

It is not yet possible to predict the future of ice sheets with any confidence. There is still lack of data of many crucial, controlling conditions at the ice-sheet bed. Therefore larger values of sea level rise due to the melting of the Greenland and West Antarctic ice sheets cannot be excluded, but likelihoods or upper bounds of sea level rise cannot be provided. However, recent signs point to an accelerating loss of ice in both Greenland and Antarctica, and some changes are exceptional when one looks over a period of centuries or millennia. The slowly evolving behaviour associated with the Greenland Ice Sheet in past decades is being transformed to more rapid changes. A zone of glacier acceleration is moving northward in Greenland, leaving Greenland's southern ice dome under threat from both increased summer melting near the coasts and increased ice discharge down glaciers that extend their influence far inland. If this continues, it is possible that the ice dome in southern Greenland will reach a tipping point, with accelerating positive feedback causing it rapid decline and an associated sea level rise of about 85 cm. The continued northward migration of the zone of glacier acceleration would make the larger northern dome also vulnerable with a risk of greater sea level rise. (UNEP 2007, 107-111; IPCC 2007a)

There have been some studies of the implications of a possible abrupt change in the Atlantic meridional overturning circulation (MOC), sometimes referred to as the thermohaline circulation, which could lead to cooling over the North Atlantic and potentially significant regional impacts over western parts of Europe. Though regarded as very unlikely (see below), potential impacts are summarised by Alcamo et al. (2007) as:

- reduced runoff and water availability in southern Europe
- major increase in snowmelt flooding in western Europe
- increased sea-level rise on western European and Mediterranean coasts
- reduced crop production with consequent impacts on food prices
- changes in temperature affecting ecosystems in western Europe and the Mediterranean (e.g., affecting biodiversity, forest products and food production)
- disruption to winter travel opportunities and increased icing of northern ports and seas
- changes in regional patterns of increases versus decreases in cold- and heat-related deaths and ill-health
- movement of populations to southern Europe and a shift in the centre of economic gravity requirement to refurbish infrastructure towards Scandinavian standards

The IPCC concludes that it is very unlikely that the MOC will undergo a large abrupt transition during the 21st century (IPCC 2007a); rather, it is very likely that the MOC will slow down, with an average model-estimated reduction by 2100 of 25%. In this case, temperatures are projected to warm over the North Atlantic and Europe, despite the projected MOC slowdown, due to the much larger influence of the increase of greenhouse gases (IPCC 2007a).

The world's terrestrial ecosystems are projected to continue as a net carbon sink for a number of decades. However, it is likely that the terrestrial biosphere will become a net source of carbon during this century. Methane emissions from tundra, frozen loess and permafrost have accelerated in the past two decades and are likely to accelerate further. With the current levels of greenhouse gas emissions, the positive trends in terrestrial carbon sink will peak before mid-century, then begin diminishing, tending strongly towards a net carbon source before 2100 while the buffering capacity of the oceans begins to saturate. Dieback of much of the Amazon rainforest, a major carbon sink, due to desiccation is a major vulnerability, but with a high degree of uncertainty. (IPCC 2007 b, 4/3)

Accelerated climate change would exaggerate considerably the impacts of gradual climate change and the changes would very likely exceed the ability of both human and natural systems to adapt. For example, accelerated climate change would lead to severe water stress in many regions of the world, substantial reductions in crop productivity and would threaten many natural ecosystems. The faster the rate of climate change, the less time there is to adapt, the more dangerous climate impacts are likely to be and the higher the potential for surprises. There exists an inverse relationship between the interval of time available for adaptive change and the likelihood for and intensity of violent conflict, trauma and coercion accompanying the process of adaptation (Barnett 2001, 3; Falk 1971, 353; Arnell 2006, 3 – see section 5.6, below).

5.4. ***Economic impacts of climate change***

Economic impacts of climate change at the global and regional level have been estimated using a range of methods. Some studies estimate the costs as a percentage share of GDP, others as a welfare loss. One type of estimate is the social cost of carbon (SCC), which is an estimate of the economic value of the extra or marginal impact caused by the emission of one more tonne of carbon in the form of CO_2 at any point in time. SCC can also be interpreted as the marginal benefit of reducing carbon emissions by one tonne (IPCC 2007, 20/14).

In the Stern review, the potential costs of climate change have been estimated using a welfare economics framework. In this approach, the objective of policy is to maximise the sum across individuals of social utilities of consumption. Consumption involves a broad range of goods and services including education, health and the environment. The relationship between the measure of social well being and the goods and services consumed by each household, on which it depends, is called the social welfare function (Stern 2006, 8).

Climate change is projected to have large consequences for the global economy. The IPCC reports estimates of global mean losses of between 1-5% GDP for 4ºC of warming (IPCC 2007b). Aggregate estimates of costs mask significant differences in impacts across sectors, regions, countries, and populations. In some locations, especially in developing countries, and amongst some groups of people with high exposure, high sensitivity, and/or low adaptive capacity, net costs will be significantly larger than the global aggregate.

The Stern Review estimates that the total cost of Business-as-Usual climate change over the next two centuries equates to an average welfare loss equivalent to at least 5% of the value of global per capita consumption. If factors such as a possibly higher-than-expected responsiveness of the climate system to greenhouse gases, direct impacts on the environment and human health, and the disproportionate burden of climate change impacts on the poor regions of the world, are taken into account, the cost could increase to the equivalent of a 20% cut in per capita consumption. However, there are large uncertainties in the calculations. There is sparse or non-existent information on the impacts of high temperature increases, especially from developing regions. There is also little information on abrupt and large-scale changes in the climate system. Putting monetary values on health and environment can be problematic, but climate change is expected to reduce welfare even more if non-market impacts are included in the analysis, if feedbacks are taken into account in climatic response to rising greenhouse gas emissions, and if implications of risks are considered (Stern 2006, 144; 163).

Effects of climate change are global, inter-temporal and can be highly inequitable. Climate change has the potential to have significant effects on prosperity and human development, because it has profound implications for the environment in which social and economic activity takes place. The impacts of climate change can have macroeconomic consequences through (Stern 2006):

1. its direct effect on output, for example when agricultural productivity is reduced because of a deteriorating environment.
2. increased depreciation of capital, because of both direct impacts from climate change and accelerated economic obsolescence due to the need to change technologies at intervals to suit the changing climate.

3. adverse impacts on people's skills and health, especially in poor communities, so that a given rate of population growth is associated with lower GDP growth. A severe climate change could also affect economy-wide productivity if its ability to assimilate new techniques, contribute to innovative research and import and adapt new technologies were impaired. This could be the case especially in countries already suffering low growth and with lesser technological capabilities. Over the longer term, the consequences for growth rates will depend on how saving rates, investment rates in different types of skills, knowledge and physical capital, rates of capital depreciation and population growth rates react. It seems likely that economic growth would be adversely affected, the more so as the effects of climate change accumulate.

It is estimated that the largest damages and also costs of climate change will likely be borne by poorer countries. For some regions in high and mid latitudes, initially and for increases of global mean temperature < 1-3ºC above 1990 levels, some impacts of climate change are projected to produce benefits. However, as warming gets larger it is very likely that all regions will experience either declines in net benefits or increases in net costs. Richer countries bear larger damages because their climate sensitive economic sectors are large. However, as a fraction of GDP, poor countries still have larger impacts. This is due to their lower capital stocks, and poorer technological and adaptation capacity. It should be noted that the aggregate costs of impacts mask significant differences in impacts across sectors, regions, countries and populations, and rich countries also have regions, sectors and groups of people with poorer adaptive capacity (Mendelsohn et al. 2006, 173-174; IPCC 2007b, 16; O'Brien et al. 2006).

At the global level, estimates of the costs of achieving different long-term stabilisation levels have been summarised by the IPCC and are shown in **Error! Reference source not found.**. The Commission of the European Communities (2007a) estimates that costs of investments in carbon low technologies and emissions reduction to reach the EU 2ºC target would not be very high measured as a share of GDP. The requirement for this is that there is a broad participation through international agreement. All countries, including developing countries, would have to take reasonable measures to improve their energy efficiency and implement additional measures to reduce emissions in sectors such as transport and residential. The energy intensive sectors would need to be integrated into a global carbon market to ensure cost efficient emissions reductions on a global scale. Developed countries would need to take on individual reduction targets of around 30% in 2020 compared to 1990 levels and have full access to the global carbon market. By 2030, developed countries would need to adopt individual emission reduction targets between 40 to 55% compared to 1990 levels. By then all countries, except low income developing countries, would have fully integrated their energy intensive sectors into the global carbon market.

Table 11 Estimated global macro-economic costs in 2030 for least-cost trajectories towards different long-term stabilisation levels (IPCC 2007c, 16).[15]

Stabilisation levels (ppm CO_2-eq)	Median GDP reduction (%)	Range of GDP reduction (%)	Reduction of average annual GDP growth rates (percentage points)
590 - 710	0.2	-0.6 – 1.2	<0.06
535 - 590	0.6	0.2 – 2.5	<0.1
445 - 535	Not available	<3	<0.12

[15] For a given stabilisation level, GDP reduction increases over time in most models after 2030. Long-term costs also become more uncertain. Studies vary in terms of the timing of stabilisation; generally this is in 2100 or later. GDP reduction is expressed as market exchange rates. Medians and the 10th and 90th percentile range of the analyzed data are presented. The number of studies that report GDP results is relatively small and they generally use low baselines.

If a global agreement on carbon emissions reductions is not reached and the EU carries out emissions reductions alone, benefits for energy security and air pollution in the EU would still accrue. Moreover, new economic development and new technologies would be stimulated and the long-term competitiveness of EU industry increased. The impact of autonomous EU action on its GDP would be limited, particularly if full access to project-based mechanisms were be granted. Without access to the Clean Development Mechanism, carbon prices would be 8-11 times higher (Commission of the European Communities 2007a, 46-47).

5.5. The EU 2°C target and stabilisation of greenhouse gas concentrations

The European Union has set an objective of limiting global mean temperature change relative to pre-industrial times to 2ºC warming (Commission of the European Communities 2007a). To achieve this, the EU estimates that concentrations of greenhouse gases in the atmosphere should be maintained below 550 ppm CO_2-equivalent, requiring considerable global emissions reductions (Commission of the European Communities 2007a). However, Working Group III of the IPCC Fourth Assessment (IPCC 2007c) suggests that an equilibrium warming of 2°C relative to pre-industrial is at the lowest bound of estimates for a (lower) stabilisation target of 445-490 CO_2-equivalent, which equates to a CO_2 concentration of about 350-400 ppm (Table 12).

Table 12 Characteristics of stabilisation scenarios reported in the literature since the IPCC Third Assessment Report (IPCC, 2007c)[a)].

Category	Radiative Forcing (W/m[2)])	CO_2 Concentration[c)] (ppm)	CO_2-eq Concentration[c)] (ppm)	Global mean temperature increase above pre-industrial at equilibrium, using "best estimate" climate sensitivity[b), c)] (ºC)	Peaking year for CO_2 emissions[d)] (year)	Change in global CO_2 emissions in 2050 (% of 2000 emissions)[d)] (%)	No. of assessed scenarios
I	2.5 – 3.0	350 – 400	445 – 490	2.0 – 2.4	2000 - 2015	-85 to -50	6
II	3.0 – 3.5	400 – 440	490 – 535	2.4 – 2.8	2000 - 2020	-60 to -30	18
III	3.5 – 4.0	440 – 485	535 – 590	2.8 – 3.2	2010 - 2030	-30 to +5	21
IV	4.0 – 5.0	485 – 570	590 – 710	3.2 – 4.0	2020 - 2060	+10 to +60	118
V	5.0 – 6.0	570 – 660	710 – 855	4.0 – 4.9	2050 - 2080	+25 to +85	9
VI	6.0 – 7.5	660 – 790	855 – 1130	4.9 – 6.1	2060 - 2090	+90 to +140	5
						Total	177

a) The understanding of the climate system response to radiative forcing as well as feedbacks is assessed in detail in the AR4 WGI Report. Feedbacks between the carbon cycle and climate change affect the required mitigation for a particular stabilization level of atmospheric carbon dioxide concentration. These feedbacks are expected to increase the fraction of anthropogenic emissions that remains in the atmosphere as the climate system warms. Therefore, the emission reductions to meet a particular stabilization level reported in the mitigation studies assessed here might be underestimated.
b) The best estimate of climate sensitivity is 3°C [WG 1 SPM].
c) Note that global mean temperature at equilibrium is different from expected global mean temperature at the time of stabilization of GHG concentrations due to the inertia of the climate system. For the majority of scenarios assessed, stabilisation of GHG concentrations occurs between 2100 and 2150.
d) Ranges correspond to the 15[th] to 85[th] percentile of the post-TAR scenario distribution. CO_2 emissions are shown so multi-gas scenarios can be compared with CO_2-only scenarios.

The lower the target stabilisation level, the more quickly the peak in emissions and thereafter the decline of emissions would have to occur. For a stabilisation level of 445-490 ppm, the period of peak CO_2 emissions would need to be 2000-2015, which implies that a period of overshoot would have to be tolerated before the level could be stabilised. The IPCC estimates that the global mean temperature increase for this stabilisation range would be 2.0 – 2.4ºC.[16] Other conceivable stabilisation targets are depicted in Table 12. Note that as global population growth is estimated to

[16] Equilibrium climate sensitivity refers to the equilibrium change in the annual mean global surface temperature following a doubling of the atmospheric equivalent carbon dioxide concentration. The effective climate sensitivity is a measure of the strengths of the climate feedbacks at a particular time and may vary with forcing history and climate state. The climate sensitivity parameter (ºC/Wm^{-2}) refers to the equilibrium change in the annual mean global surface temperature following a unit change in radiative forcing. (IPCC 2007a, 943)

remain positive until at least 2050, it will be more difficult to reduce emissions, as total emissions are likely to increase more rapidly than emissions per capita (Stern 2006).

The temperature changes shown in Table 12 are equilibrium responses, which would be realised only decades or centuries after stabilisation of atmospheric greenhouse gas concentrations, due to time lags in the response of the climate system (primarily the oceans) to changes in radiative forcing. There is no information provided in the IPCC Fourth Assessment Report on the transient (time dependent) climate response to CO_2 or CO_2-equivalent stabilisation during the 21st century. However, some information is provided in the Third Assessment Report on the global warming projected for different CO_2-only stabilisation levels (IPCC, 2001) and the potential impacts avoided or reduced by different levels of mitigation are illustrated in Figure 20 from that report.

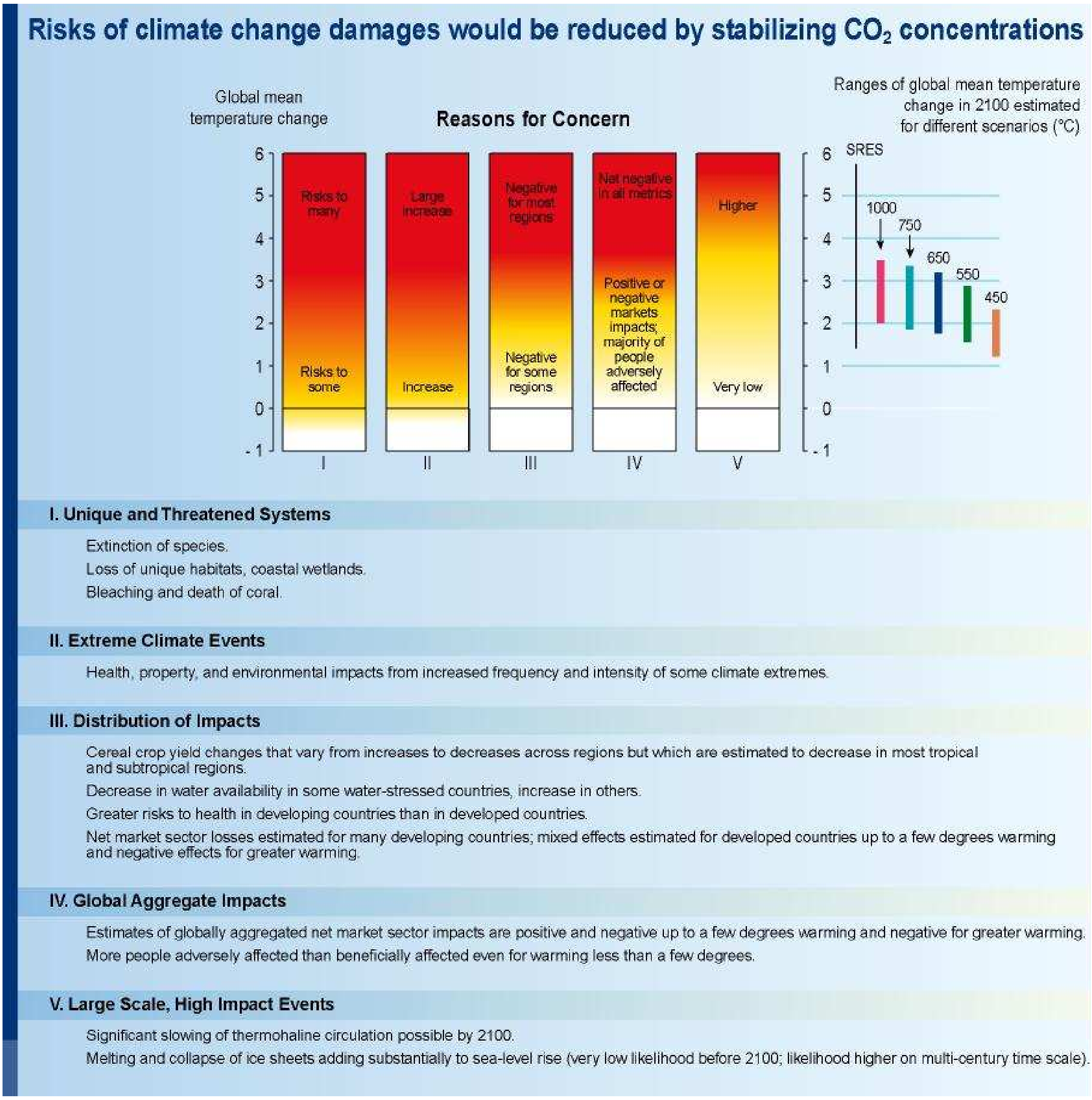


Figure 20 Risks of climate change damages and stabilisation (Source: IPCC, 2001)

5.6. Climate change and security

Security can be defined as the condition of being protected from or not exposed to danger (Barnett 2001, 2) and "the assurance people have that they will continue to enjoy those things that are most important to their survival and well-being" (Soroos 1997, 236). Climate change can be seen as a security issue for some countries, communities and cultures. Small island states, Arctic communities and people living in low-lying deltas of the world are examples of groups of people that are threatened by climate change. To them climate change poses cultural, health and life-threatening risks comparable to the impacts of warfare. However, security impacts of climate change will take less direct and more multifarious routes than conflicts do. Security is also socially constructed and therefore closely related to vulnerability (Barnett 2001).

Environmental issues including climate change cannot be considered as isolated problems but are integrally connected to problems such as poverty, health and war. Global environmental change is fundamentally a human security issue. Human security is the condition when and where individuals and communities have the options necessary to end, mitigate, or adapt to risks to their human, environmental, and social rights; have the capacity and freedom to exercise these options; and actively participate in attaining these options. Human security is a people-oriented concept that focuses on enabling individuals and communities to respond to change, whether by reducing vulnerability or by challenging the drivers of environmental change (O'Brien 2006,1-2).

Climate policy could increase security (OECD 2004, 95-96). This could happen through several channels. For example, climate policy is increasingly emphasising the diversification of energy sources, which would reduce societal and economic sensitivity to disruptions of oil and gas supply. Also, by reducing climate change damages, climate policy has the potential to avert possible security problems they might induce. Potential humanitarian crises could be reduced, such as food supply issues and other security risks, that would otherwise be likely to develop because of climate change impacts.

Climate change and security issues have received increased attention in recent months. For the first time in its history, the United Nations Security Council held a debate on the impact of climate change on peace and security on April 17, 2007[17]. The day-long meeting was called by the United Kingdom and aimed to examine the relationship between energy, security and climate. In addition, a group of United States generals recently published a report on climate change and security issues (CNA Corporation 2007). In presenting the award of the Nobel Peace Prize jointly to the IPCC and Al Gore on 10 December 2007, the chairman of the Norwegian Nobel Committee, Professor Ole Danbolt Mjøs, stated: "Those who attach importance to "human security" argue that the main thing is to protect individuals. The chief threats may be direct violence, but deaths may also have less direct sources in starvation, disease, or natural disasters. A goal in our modern world must be to maintain "human security" in the broadest sense"[18].

Three issues related to climate change and human security are discussed in this section. Firstly, conflicts that could be triggered by climate or environmental change, secondly disasters related to climate change, and thirdly forced migration as a consequence of climate change. Finally, a possible approach for evaluating environmental security is presented.

[17] http://www.un.org/News/Press/docs/2007/sc9000.doc.htm
[18] http://nobelprize.org/nobel_prizes/peace/laureates/2007/presentation-speech.html

Possibility of conflicts

A relatively stable climate has been the prerequisite for the development of human societies. Changes in climate can induce changes in natural systems that bring instability among nations. If climate changes significantly, the environmental conditions can deteriorate to the point that necessary resources are not available and societies can become stressed, sometimes to the point of collapse. Climate change can exacerbate many sources of tension and conflict that include impaired access to food and water and extreme or violent weather conditions (Diamond 2004, can Corporation 2007).

In countries, where the material well-being of the people is highly sensitive to external forces, such as changing terms of trade, or where material well-being is in decline, the governments tend to be relatively more unstable, and consequently the countries relatively more prone to internal violent conflict. This could hold true for exogenous environmental shocks as well. The increasingly frequent and severe hazardous events that are expected as a result of climate change mean more exogenous shocks to all countries and therefore possibly less security. Climate change can also undermine individual and community economic livelihood, affect human health, reduce availability of freshwater and food, undermine state wealth and military capability, and exacerbate inequalities between people (Barnett 2001, 4).

However, it is generally difficult to find meaningful evidence of the determinants of violent conflict and war and therefore it is necessary to be cautious about the links between climate change and conflict. There is some evidence, however, for general findings that include: poverty and inequality are prevalent in many cases of sub-national conflict; recent violence is a good predictor of future violence; the most important disputed issue in past violent conflicts has been territory; strong states with an ability to monopolise the use of force and manage collective actor problems, and democracies tend to be less prone to internal conflict; and violence is more likely between neighbouring groups and countries. The relationship between ecology and conflict is also complex. For example, in conflicts in sub-Saharan Africa, multiple actors are involved with divergent and often conflicting interests. The access to and control of valuable natural resources, including minerals, oil, timber, productive pastures and farming land, have been crucial factors in the occurrence of violent conflicts across the continent. In their widest sense, the use and control of ecological resources as causes of conflicts has been motivated by both grievance and greed. Moreover, grievance related to the unjust and inequitable distribution of land and natural resources in many regions of Africa, and greed for valuable ecological resources have in many instances been the underlying causes of armed conflicts (Barnett 2001, 5, Porto 2002, 3).

Climate change impacts could become one factor in the future in both national and cross-border conflicts, particularly when coupled with rapid population growth, and economic, political, ethnic or religious tensions. Long term environmental deterioration due to climate change will exacerbate the competition for resources and could contribute to forced migration, which in turn could generate destabilising pressures and tensions in neighbouring areas. Because of adverse effects of climate change, work opportunities can be reduced, making recruitment into rebel groups much easier. For example, the crisis in Darfur is thought partly to be a consequence of long periods of drought in the 1970s and 1980s which resulted in deep and widespread poverty. The risk of climate change sparkling a conflict in a country or area is larger if other factors such as poor governance and political instability, ethnic tensions and high dependency on environmental resources are already present. In light of this, west Africa, the Nile Basin and central Asia could be regions potentially at risk of future tension and conflict (Stern 2006, 12).

Disasters

Current climate already influences economic opportunities and prospects for development in many regions. Between 1970 and 1999 about 3.76 billion people were affected by natural disasters (primarily weather-related) in Asia. There is high population density in hazard prone areas in Asia, which explains the large number of people affected. Africa has the second highest number of people affected by natural disasters, largely due to frequent occurrence and long-term impacts of droughts and the importance of the agricultural sector in the continent. In Latin America, floods caused the highest cumulative costs, followed by wind storms, earthquakes and droughts (Sperling 2003, 6).

A disaster can be defined as an extreme event with adverse consequences that are beyond the scope of typical coping mechanisms. These adverse consequences may be loss of life, loss of property, loss of resources.[19] Disasters are also primarily the result of human actions. While hazards are natural, disasters are not. Social systems generate unequal exposure to risk by making some people more prone to disaster than others. These inequalities are largely the function of power relations (factors such as class, age, gender and ethnicity among others) operating in every society. Vulnerability is highly differentiated and some people and some regions are more vulnerable than others. Therefore, whether a natural event is a disaster or not depends ultimately on its location (Smith 2006, Bankoff 2006). Moreover, disaster is not defined in terms of the event itself, but in terms of both the processes that set it in motion and the post-event processes of adaptation and adjustment in recovery and reconstruction. Disasters are determined by a range of factors of different orders: cultural, social, environmental, economic, institutional and political, and their relations (Oliver-Smith 2006) .

Disasters have lately increased in impact and scope through the combined effects of economic, social, demographic, ideological and technological factors. Greater numbers of people are now more vulnerable to natural and other hazards than ever before, due in part to increases in population, but more so to their location in dangerous areas. The increasing complexity of disasters is rooted in the interplay of social and economic factors in the environment, exacerbating the vulnerability of people and environments and intensifying their impacts when they occur. Hurricane Katrina's impact on New Orleans was compounded by an excessive dependence on technology and half a century's assault on the natural defences of the environment of southern Louisiana, leaving the city tragically vulnerable. Also, like with most climate hazards, hurricane Katrina did not affect everybody equally. Issues of race, age, gender, and economic class influenced who was able to respond, both in anticipation and reaction to the storm (Oliver-Smith 2006, O'Brien 2006, 2).

Forced migration

There is currently no category for "environmental refugees" in the United Nations Refugee Agency UNHCR classification of refugees. However, the UNHCR estimates that there are millions of people displaced directly or indirectly by environmental degradation and natural or man-made disasters in the world (UNHCR 2006). Migration, whether permanent or temporary, has always been a traditional response or survival strategy of people confronting the prospect, impact or aftermath of disasters (Oliver-Smith 2006). People have also historically left locations with harsh or deteriorating conditions. Examples in the past that indicate that there is a relationship between human population movements and climate include the climate of the US Great Plains in the 1930s, drought migrations in East Africa, and consequences of hurricane Mitch in 1998. However, in a multidimensional world, people's decisions to migrate or stay are influenced by a huge range of

[19]Workshop Report, Udall Center, University of Arizona: http://udallcenter.arizona.edu/publications/swclimate/ch17-disaster.html

factors, and environmental change is seldom the only explanatory factor (Black 2001, 14; McLeman and Smit 2004, 6-7).

Several definitions of environmental refugees have been presented in the literature. El-Hinnawi (1985) and Jacobson (1988) divide environmental refugees into three categories, namely persons experiencing temporary displacement due to temporary environmental stress, permanent displacement due to permanent environmental change, and temporary or permanent displacement due to progressive degradation of the resource base. Other definitions of environmental refugees have been based on distinctions between emergency or slow-onset movements, temporary, extended and permanent movements, and internal and international movements. Environmental migration has also been divided into migration stimulated by deforestation, rising sea levels, desertification and drought, land degradation, and water and air degradation (Barnett 2001, Suhrke 1993).

There is little question that some disasters, but not all, force people to migrate. Most migration is not international but occurs within individual countries, and most international migration occurs between developing countries. Much migration is seasonal and cyclical rather than permanent. The best predictor of migration patterns in the future is recent migration patterns. People rarely migrate for environmental reasons alone, but migration can be attributed to a complex pattern of factors including political, social, economic as well as environmental forces (Figure 21). Natural disasters can cause temporary displacement, but if permanent migration occurs as the result of a disaster, the reason for it could be more the deficient responses of weak or corrupt states than the environmental conditions. The role of the state is important: a strong, efficient state can deal with environmental problems much better than a weak state. Therefore, the key problem is perhaps not environmental change itself but the ability of different communities and countries to cope with it. Also, the combination of increasing population, population density, increasing poverty, and occupation of hazardous sites has accentuated vulnerability to both natural and technological hazards and increases the probability of forced migrations (Döös 1997; Oliver-Smith 2006; Barnett 2001, 8; Castels 2002, 4-5).

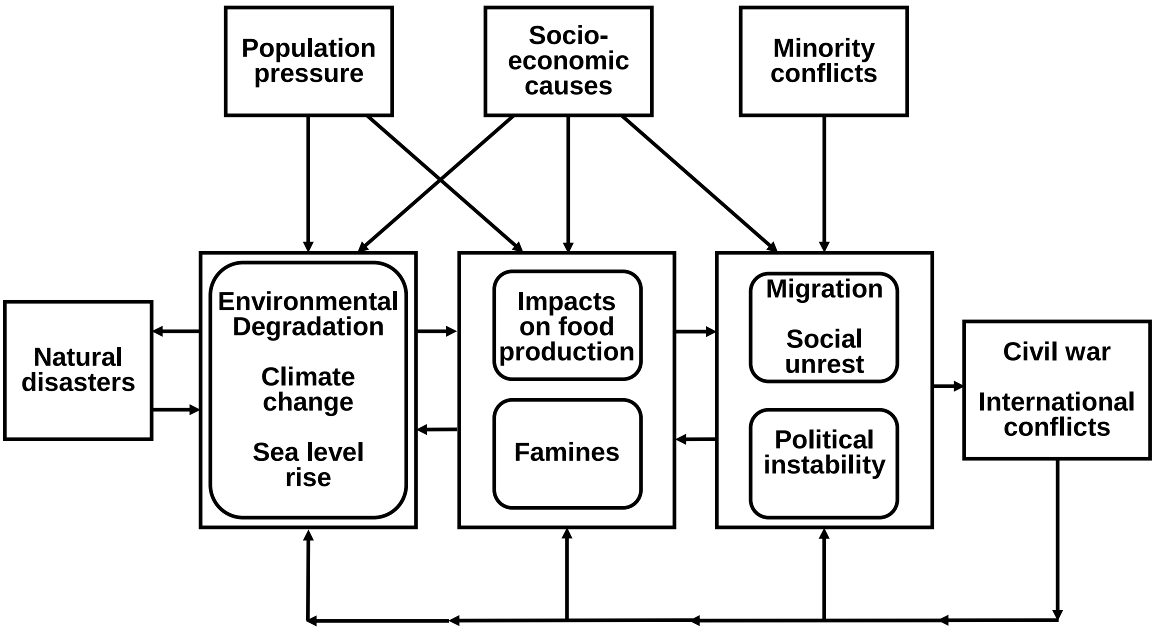


Figure 21 Interconnections between the major factors that can influence or reinforce environmental degradation, resulting in an increased risk of environmental migration (after Döös 1997)

Climate related migration could function in different ways. These include: a formation of repetitive migration patterns as part of an ongoing adaptive response to variations and changes in climate; short term shocks of migrants with a particular climatic stimulus; large scale movements of people that build slowly but gain momentum as adverse climate conditions coincide with other adverse socio-economic conditions or processes. However, migration is not always the adaptive response taken by the population in communities with adverse climate impacts. Also, those that migrate, do not necessarily share the same demographic characteristics as the population at risk. Migrants are often young males as in the case of drought s in East Africa. These were not, however, the typical demographic characteristics of those most adversely affected: landless people, rural poor, the sick or elderly, those with little family support. The most vulnerable are not necessarily the most likely potential climate change migrants. Altogether, the total number of people at risk of displacement or migration in developing countries is very large ranging from the millions of people at risk of malnutrition and lack of clean water to those millions currently living in flood plains. However, the exact number of people who will actually be displaced or forced to migrate will depend on the level of investment, planning and resources at a government's disposal to defend these areas or provide access to public services and food aid (McLeman and Smit 2004, 9; Stern 2006, 111).

Measuring environmental security

In an attempt to quantify the actual or predicted occurrence of "crisis events", Alcamo et al. (2001) suggest the construction of security diagrams (Figure 22). The data points in these diagrams depict the level of environmental stress and corresponding state susceptibility of a particular country or geographical unit at a particular point in time. The data points shaded red in Figure 22 indicate that a crisis of environmental origin occurred at this time and in this country. Other points show instances (e.g. years) with no crisis. The type of crisis matches the type of environmental stress depicted in the diagram.

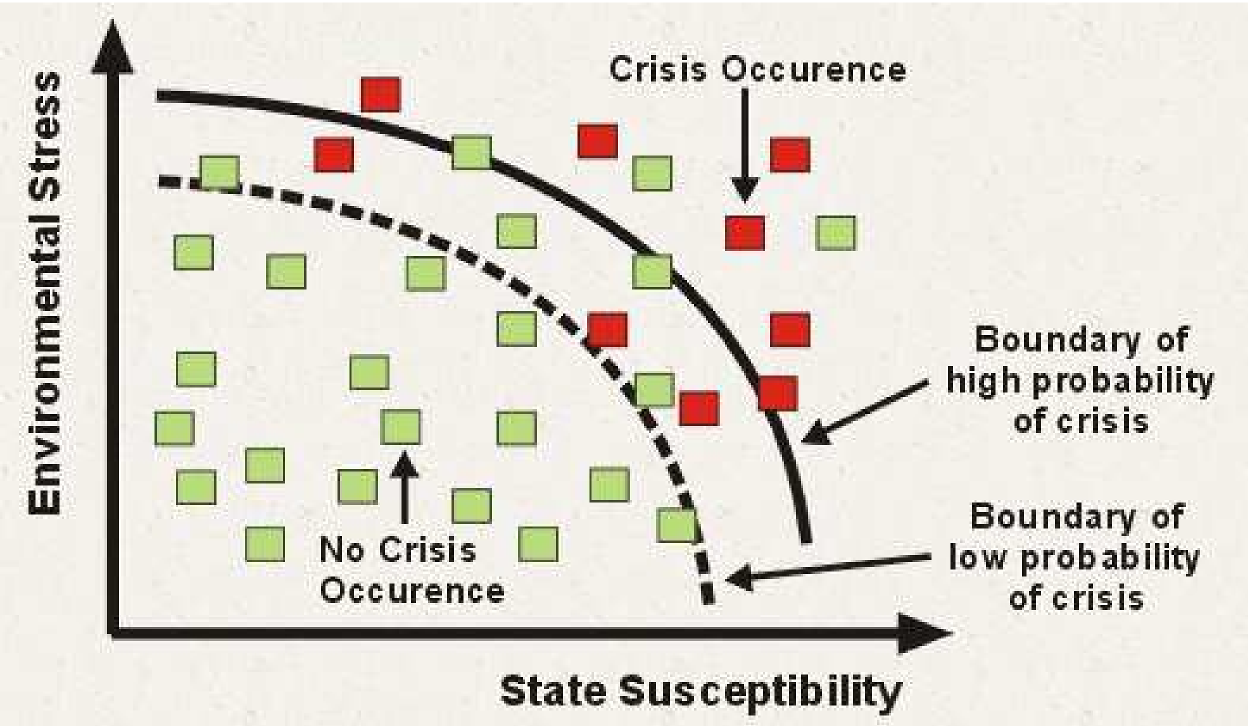


Figure 22 Example of a security diagram (Alcamo et al. 2001)

Alcamo et al. (2001) use the concept of transient environmental stress, defined as the intensity of an environmental change that: (i) involves an undesirable departure from long-term or "normal" conditions, (ii) is of short duration, (iii) is directly or indirectly influenced by society, and not only the result of natural geological factors (as in the case of volcanoes and most earthquakes). They use two examples: deviations from "normal" in water availability and in potential crop productivity in a particular year, both computed over a gridded global database.

"State susceptibility" is defined as the capability of a state to resist and/or recover from crises brought about by environmental stress. This could thus be regarded as a measure of adaptive capacity, and Alcamo et al. use GDP/capita as a crude measure of state susceptibility in the case studies they present. The higher the stress, the more frequent the occurrence of crisis events. Likewise, the higher the state susceptibility, the more frequent the crises. Also, if state susceptibility increases, then a lower stress is required to cause a crisis. Hence, crisis events are concentrated in the upper right part of the diagram, as shown in Figure 22. However, since the selection of a boundary demarcating a crisis from no crisis based on these crude criteria is necessarily uncertain, Alcamo et al. (2001) depicted this in terms of a high or low probability of crisis. They also discuss how social learning in the face of crises (i.e. the implementation of adaptive strategies) may reduce state susceptibility, which would shift the curved boundary outwards towards the top right.

In case studies focusing on African vulnerability to food crises, Alcamo et al. (2001) attempted to quantify the risk of annual yield shortfalls using an integrated assessment model, GLASS (Global Assessment of Security). Figure 23 illustrates how such an assessment can make use either of historical data (in this case, observed climate over the 20th century) or scenarios (here scenarios of future GDP per capita and climate).

Environmental stress is defined as the crop area where potential productivity is 50% or below its climate-normal value. For the reference period 1901-1995, six countries have a high potential for food crisis during 50% or more of these years (Figure 23a). In a future period 2001-2050, many countries become less susceptible to crisis because of assumed increases in GDP per capita, and the number of countries in the highest risk category drops to three (Figure 23b). However, including a scenario of climate change in the calculations means that many countries experience higher levels of environmental stress, and the number of countries in the highest risk category increases back to six (Figure 23c).

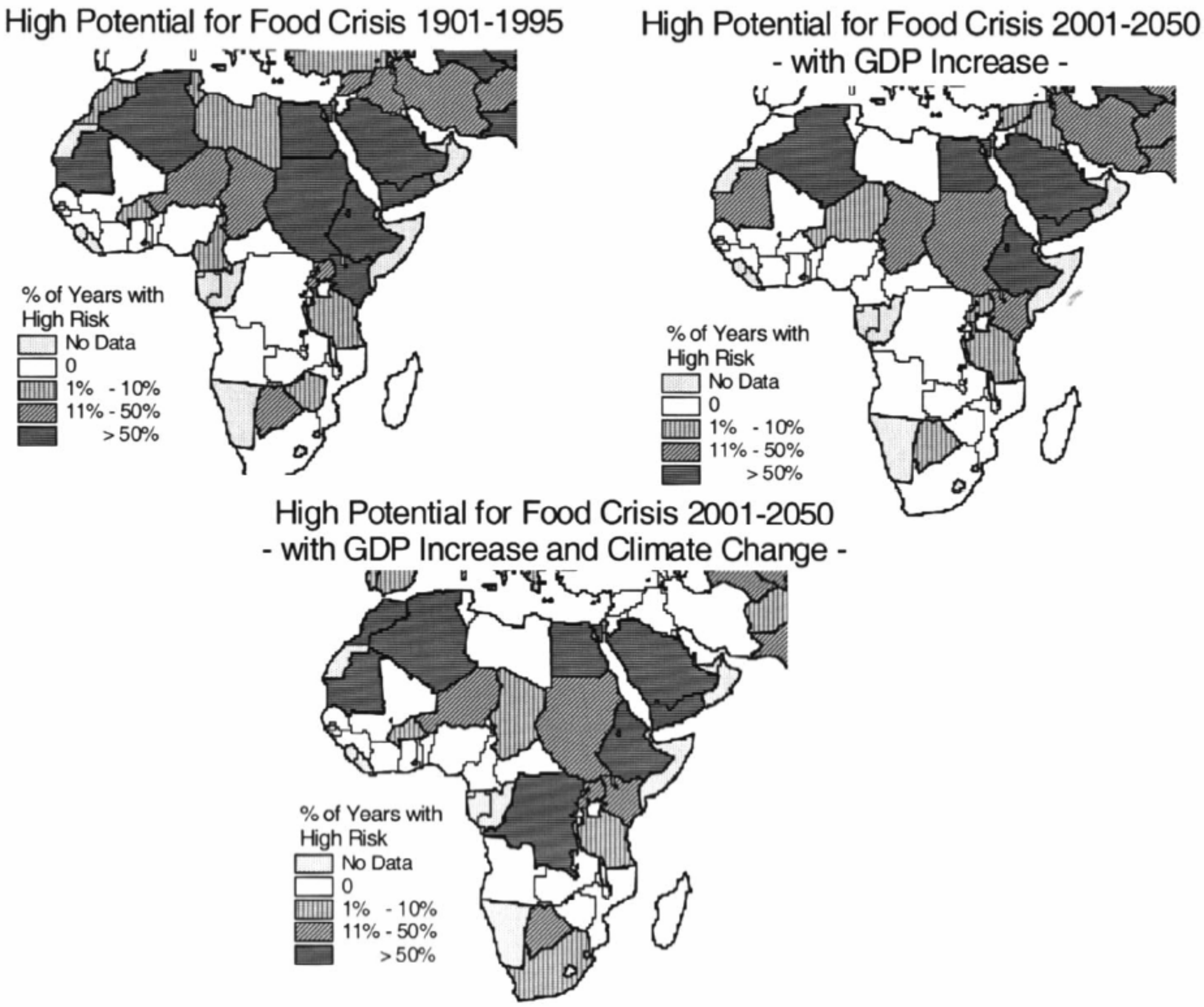


Figure 23 Frequency at which countries in Africa are computed to have a high potential for food crisis. (a) Between 1901 and 1995. (b) Between 2001 and 2050 with GDP increase. (c) Between 2001 and 2050 with GDP increase and climate change (Source: Alcamo et al. 2001).

6. Implications of climate change impacts for Finland

It is estimated that, at least in the near future and with moderate rates of climate change, the impacts of climate change will be mixed in Finland (Marttila et al. 2005; Carter, 2007). There will be some costs, but also some benefits. The more severe impacts in the near future are expected elsewhere: in developing countries, and at lower latitudes (IPCC 2007b). However, vulnerability to climate change is a dynamic concept and changes over time. In the long run, it is also possible that potential "winners" under climate change – such as some groups or sectors in Finland – may in fact become losers. This could be due to political and economic instability stemming from climate related impacts in other countries or regions of the world. Furthermore, the magnitude of climate change in the long run may surpass critical thresholds of tolerance or trigger catastrophic events, thereby transforming benefits to losses (O'Brien et al. 2003, 99).

6.1. Implications for some Finnish sectors

The Finnish national climate change adaptation strategy (Marttila et al. 2005, 238-239) identified some sectors in Finland that could be affected by global climate change impacts. These sectors were agriculture and food production, forestry, water resources, tourism, transport, energy and insurance. Development co-operation issues and adaptation to mitigation measures were also discussed. Climate change is expected to have direct impacts on the climate sensitive sectors in Finland, such as agriculture, but the sectors could also experience indirect impacts that are consequences of climate impacts happening elsewhere in the world.

Agriculture

Climate change is expected to affect agricultural productivity worldwide. Production conditions are expected to deteriorate severely in Africa, and also in Latin America, whereas they are likely to improve under moderate warming in higher and mid-latitude areas. This trend may be reversed with higher levels of climate change. However, even low levels of climate change are expected to be detrimental to agriculture in Southern Europe. Overall, if the major food production areas of the world are affected negatively, this could improve the relative competitive position of northern European and Finnish agricultural production in food markets, which could mean that agricultural production in Finland might have the potential to expand. However, agricultural production in Finland and its competitive position are also dependent on other factors than climate (e.g. the changing competitive position of agriculture in Eastern Europe, land use and land prices, and agricultural policy) and these are likely to have a dominant influence on future developments in the sector (Hildén et al. 2005, 19).

For instance, Berry et al. (2006) report a recent model-based study of future agricultural land use in Europe under a changing climate. The land use model combines two sub-models that simulate crop growth and farm level decision processes. Using scenarios of future climate and assumptions about future adaptation policies (based on an interpretation of alternative socio-economic scenarios and narrative storylines closely related to SRES[10]), they estimated that agriculture in southern Finland would intensify under most scenarios (primarily due to improved growing conditions and enhanced technology). However, intensification was not estimated in a future regionally-focused and environmentally-orientated world in which crop yield gains due to technology are assumed to be limited, climate changes are small and extensification of agriculture is encouraged through policy measures (Figure 24).

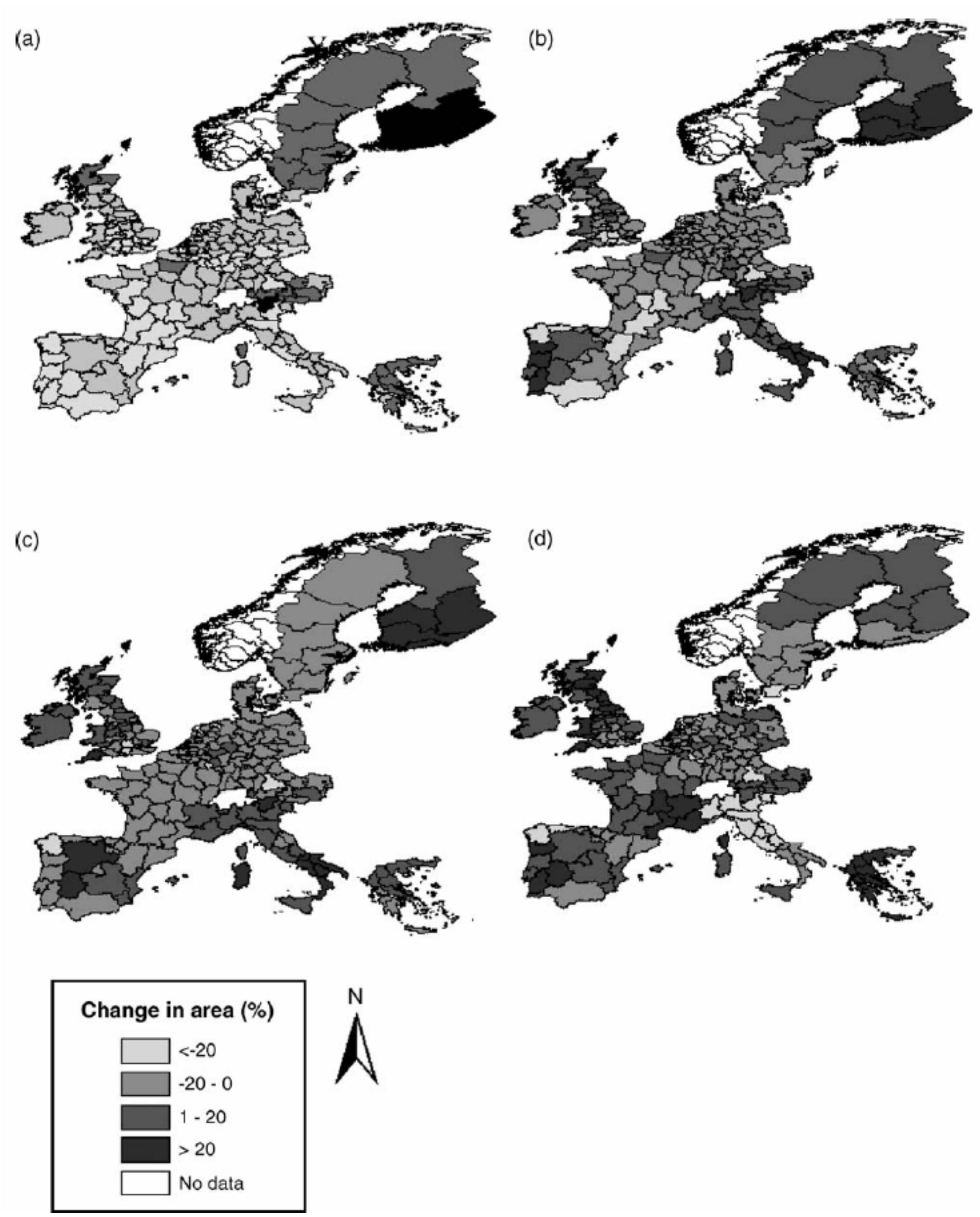


Figure 24 Change in area of intensive agricultural land use by 2050 for the HadCM3 climate and socio-economic, technological and policy assumptions assumed consistent with the four SRES storylines: (a) A1FI (labelled "world markets"), (b) A2 ("regional enterprise"), (c) B1 ("global sustainability") and (d) B2 ("local stewardship"). Source: Berry et al. (2006).

Mitigation measures, such as increased demand for bio-energy crops or restrictions in use of fossil fuels, can also have impacts on Finnish agriculture. The European Community's objectives for 2010 concerning renewable energies are: a 12% share in total energy consumption, a 21% share in gross electricity consumption and a 5.75% share in vehicle fuel consumption[20]. These policies, together with the increase of energy prices, would enhance the competitiveness of bio-energy crops. Part of agricultural production could shift into bio-energy crops which would affect markets and prices of agricultural products. Increased bio-energy crop cultivation would also require more agricultural land. Competition for land for different purposes might then become stronger and prices of land

[20] http://ec.europa.eu/energy/res/sectors/bioenergy_en.htm

increase. However, currently there is an abundance of agricultural land in Finland relative to current production volume, so there is potential for expansion of crop and bio-energy production (Hildén et al 2005, 19). Moreover, restrictions in the use of fossil fuels could affect the productivity of agriculture, which might also require increased agricultural areas to be taken into production.

Forestry and forest industries

The forestry sector in Finland has undergone many changes during recent decades. The export value of the forest industry has decreased from 42 % in 1980 to 20% (2004). The share of the forest sector in GDP has also decreased; in 1980 forest industries and forestry together constituted about 11% of GDP while in 2004 this had fallen to about 5%. Investments of Finnish forest industries abroad have increased substantially during the past decade. In 1980, almost 90% of the capacity of Finnish forest companies was in Finland, but currently only about 40% of the production is in Finland even though the capacity has increased. Other changes and trends predicted to continue in the future are increased consideration of environmental issues, larger and more global forest companies, industries situating globally close to raw materials and markets, globalisation of the sector, new products, and changes in consumption of forest industry products around the world. In the OECD countries, consumption of forest industry products is growing slowly or not at all, but it is growing fast in, for example, many Asian countries and Russia. Growth prospects of forest industries in Finland are in highly refined products or totally new ones; traditional products appear to have reached an upper limit. It is likely that the use of wood in Finnish forest industries for current products will decrease in the future. It is also unclear whether the reduction will be allocated to Finnish wood or to imported wood (Seppälä 2000a,b; Rytkönen 2000; Hetemäki et al. 2006; Kalela 2005; Hänninen 2005).

Forest bio-energy use in Finland has increased steadily over time. Use of bio-energy is promoted by issues such as increasing prices of energy and by climate mitigation policies and EU targets. Bio-energy will create new business opportunities for the Finnish forestry sector but it also likely to have negative effects, such as impacts on the biodiversity and ecology of forests (Hetemäki et al. 2006).

The Finnish forestry sector can contribute to climate protection by increasing the forest area and growth. Both of these are happening currently without extra effort. There are also so called win-win solutions for carbon sinks. For example, the use of wood as a building material could be increased at the expense of materials such as concrete and metals. Finnish plantations in other countries serve as a store of carbon without any additional costs, if the costs of plantations can be covered by the raw materials being produced. It is also possible that the sole reason for growing forests in the future could be as carbon sinks. The costs of such a strategy are currently approximately the same as those of emissions reductions in industry and energy production, and this is not yet regarded as a feasible option. There is also competition between different land uses and it could be difficult to demarcate forest areas as carbon sinks (Kauppi 2005; Granholm 2005).

Nature-based tourism is projected to increase in the future and the number of foreign tourists is expected to grow. This could lead to changes in the use of Finnish forests, at least in some regions, and perhaps requiring that larger forest areas be taken out of commercial use. The enhancement of biodiversity and nature conservation may also require a change of use out of commercial forestry (Hetemäki et al. 2006).

During recent years, the Finnish forest industry has been investing in large pulp mills and plantations in Latin American countries. The investment period for pulp mills is long, 30-50 years, and the mills are dependent on plantations for their raw materials; climate change could have adverse effects on these in the future.

International mitigation policies could also have impacts on the Finnish forestry sector. An increased share of renewable energy, by increasing demand for wood as an energy source, could affect prices of wood and availability of wood for industry, building and other uses. Increased renewable energy demand and other mitigation policies such as the use of forests as carbon sinks are likely to require alterations in forestry practices and management.

Tourism

The tourist flow of northern Europeans to the Mediterranean countries is the single largest flow of tourists across the globe. In 2000, this accounted for one-sixth of all tourist trips, or around 100 million tourists per year (Commission of the European Communities 2007a, 23). Summer tourism in the Mediterranean (along with winter tourism in the Alps) is expected to be adversely affected by climate change, and there are already early indications of this (IPCC 2007b) The pattern of summer conditions could change dramatically in the course of this century as a result of climate change. The zone with conditions judged to be excellent for beach tourism, which is currently located in the Mediterranean region, could shift northwards, perhaps as far as the North Sea or Baltic Sea. Moreover, limitations on water availability could also affect tourism negatively in the Mediterranean as climate change proceeds. On the other hand, conditions for tourism could improve in that region in autumn and spring.

The outcome of these changes for the tourist industry will be determined by the tourists' responses to the changes. Some tourists may stay at home, which would also increase domestic tourism in Finland. Others will switch their holiday destinations, which will have implications both for tourism and distributional impacts in Europe in general and in Finland. How large the distributional impacts will be depends on the adaptation of tourists, tourist businesses and societies (Commission of the European Communities 2007a, 23-24, Sievänen et al 2005).

Mean monthly snow cover extent in the northern hemisphere declined at a rate of 1.3% per decade during 1966-2005. Mountain regions are particularly sensitive to climate change and increases in mean minimum temperatures are more pronounced at higher elevations than in valleys. It is estimated that the snow line of the Alps will rise about 150 m for every 1.0º C increase in winter temperatures. The Alps and Pyrenees are projected to experience warmer winters with possible increases in precipitation, which will raise snow lines and reduce overall snow cover. The Alps are currently warming at roughly three times the global average. The rise of snow line with rising temperatures will result in a decline in snow conditions which means that more and more of the current ski operations will not be viable any more. Adaptation measures, such as artificial snow making and building ski resorts at higher elevations, will make it possible for winter tourism to continue. However, with increased warming, many low-elevation ski resorts will no longer be able to adapt and will have to switch to other types of tourism or close (UNEP 2007, 42; 44; 56). As the skiing conditions in the Alps deteriorate, it is possible that the number of tourists visiting Finland to ski will increase. It is also possible, that tourists could change their behaviour and switch to other sports and recreation types.

Insurance

Insurance can play a substantial role in managing and spreading risks associated with increasing extreme weather events across time, over large geographical areas, and among communities and businesses, both because of its financial capacity and its ability to encourage loss-reducing behaviours more effectively than public sector efforts. By pooling risks among those insured, insurers reduce the potential economic exposure of any individual or firm to a manageable level.

Insurers can also serve as proactive risk managers by endorsing or requiring loss-prevention behaviours or technologies. The availability and affordability of insurance are prerequisites for economic development, financial cohesion of society and security (Mills 2005, 1040; 2007, 810).

The costs of weather-related natural events globally have been rising during the past decades (Figure 25) and there is evidence that changing patterns of extreme events are drivers for these losses. The insured share of total economic losses from weather-related catastrophes is rising as well. Global weather-related losses have also been trending upwards much faster than population, inflation, or insurance penetration, and faster than non-weather-related events. The cited magnitude of losses also systematically underestimates actual costs to insurers and the economy as a whole, as small events that are however large in aggregate, are seldom captured in the statistics. Analyses of long-term records of disaster losses indicate that societal change and economic development are the principal factors responsible for the documented increasing losses to date (Mills 2005, 1041; Munich Re 2006).

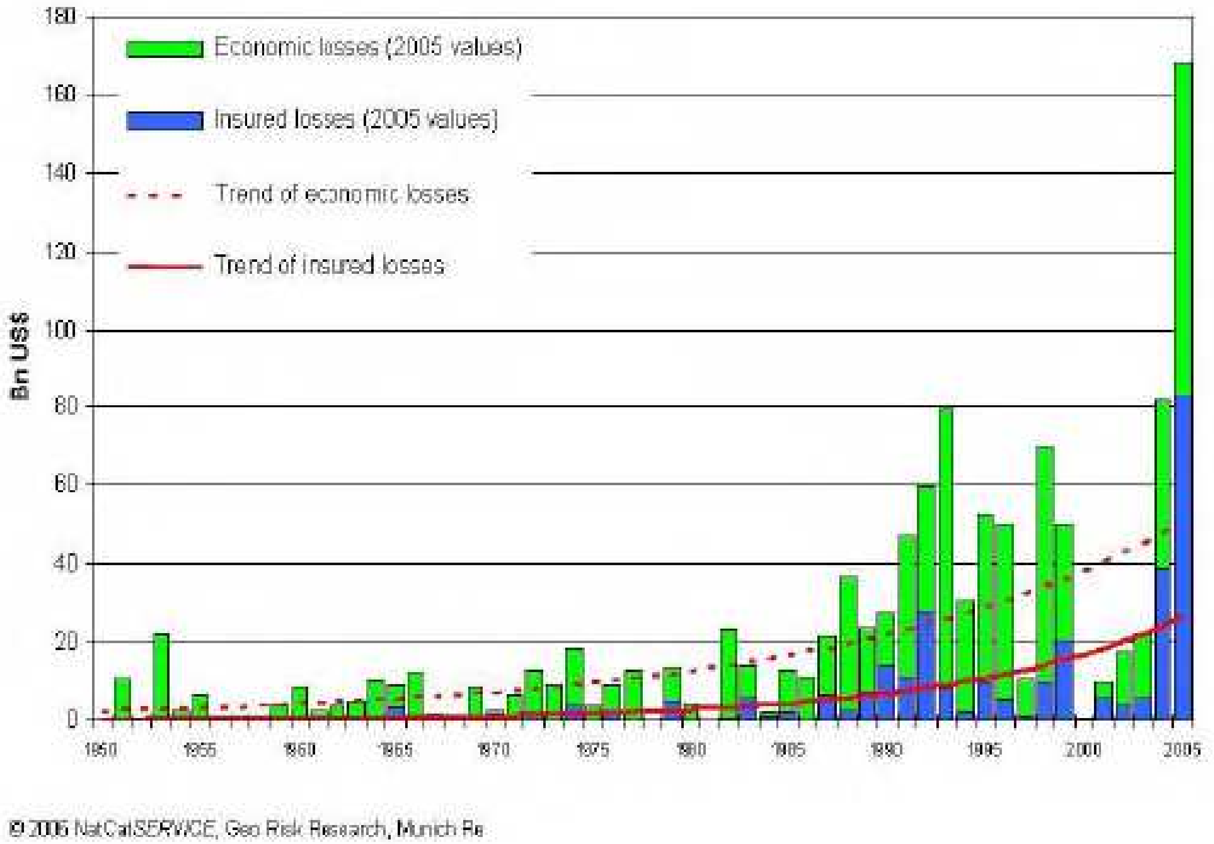


Figure 25 Global trend in losses due to great weather disasters (Munich Re 2006).

Climate risks are not only related to a possible increase in extreme climate events. Also "normal" weather conditions are changing. Climatic anomalies can be understood as atypical, unusual, out-of the ordinary weather conditions, of which there is no previous experience and which could not be expected in that form, in that location or at that time of year. Climatic anomalies, even if they are not catastrophic weather conditions, can cause large losses. Examples include losses and damages of past warm summers of 1992, 1995 and 2003 in Europe. Impacts of climatic anomalies can vary substantially, depending on the system concerned. For example, warm summers are not necessarily a negative issue for everyone. Also, many of the negative effects of climatic anomalies are difficult to notice as they usually materialise in private or there is a time lapse between the anomaly and the impact (Swiss Re 2002, 12-14).

Most forms of insurance are affected by the likely impacts of climate change, including damages to property, crops and livestock, pollution related liabilities, business interruptions, supply-chain disruptions or loss of utility service, equipment break-down and health and life consequences (Mills 2005, 1040). The role of the insurance industry in relation to climate change is to identify risks, make sure that the risks are perceived by those affected, analyse the risks, assist in reducing climate risks by supporting climate protection, and to facilitate insurance to weather risks despite climate change and to continue providing cover which is both affordable and adequate. Carrying of risks for the insurers involves correct pricing of risks, retentions to promote loss prevention, setting limits to compensation, surveillance of risk accumulation and reinsurance arrangements, loss prevention, and exclusion of certain risks and geographical areas (Swiss Re 2002, 24; Kivisaari 2005, 10; 2007, 28).

In a stationary climate, the sum of all weather-related losses and damages would be calculable over long periods. The more variable the climate, the more variable the extent of the damage per time unit and the more difficult to estimate weather risks reliably. For the insurer, this means an increased risk of a very high loss burden. The profitability of the insurance industry is threatened if the trends of the recent decades continue and some new threats arise. The combined effect of increased losses, pressure on reserves, inflation of construction costs following natural disasters, and rising costs of risk capital result in a gradual increase in the number of years in which the industry is not profitable. The insurance industry can in this case only react by increasing the burden on the individual insured parties, either by limiting the compensation paid in the event of loss, by raising premiums or by demanding greater efforts to limit or mitigate the extent and probability of the damage or losses to be insured. The idea of insurance is not to bear losses, but to spread them throughout the insured community on the basis of solidarity (Mills 2005, 1042; Swiss Re 2002, 23).

The challenge to the insurers is to analyse the need for additional capital in relation to the risks. In the past, increase of capacity has been channelled thorough reinsurance. So far it has been possible to pool large and rare risk in an efficient manner. This might not be possible in the future though, as risk becomes larger. Insurance terms could be changed in a way that part of the risks will be transferred to primary insurers. Primary insurers will have to start reconsidering their insurance terms: costs, insurance takers own risk, mitigation of risks, etc. Therefore, the roles of private insurers and governments in risk bearing have to be re-valuated and alternative risk transfer instruments need to be developed (Kivisaari 2005, 11-12).

Governments may also need to have a role in carrying the risks if the risks of very large numbers of people being affected become too large, as the possibility for insuring risks is related to the magnitude of catastrophes. Some risks can be too large for the capacity of insurers to bear them. Also, if risks are not distributed evenly, insuring them will be more difficult. The government may have a role in offering emergency help or in covering the costs and repairing the damage. Traditionally the role of government has been emergency relief, but increasingly governments are being called on to repair damage (e.g. in the U.S. after hurricane Katrina). One solution could be enforcement of obligatory insurance, for example, for flood damages (Kivisaari 2005, 11, 13).

Adaptation to climate change, which means preventing losses and ensuring that loss occurrences are the exception rather than the rule, is crucial from the insurer's point of view as well. Lives of people and systems need to be shaped in a way that average weather conditions only rarely trigger damage or loss. Also, solidarity in this situation no longer makes sense. If individuals suffer regular losses because they have failed or have been too slow to adapt to the changed climate, the other members should not be expected to share the burden anymore if they themselves have made great efforts to adapt to the new conditions. If damage becomes the rule for all members, because they have not been able to adapt in time or at all, everyone will have to pay for his own loss or damages and insurance would be unnecessary. So the aim has to be to prevent an increase in weather-related damage and losses, if possible. The total loss burden will be determined by how a society is able to cope with the risks of climate variation and change (Swiss Re 2002, 23).

Energy

The development of renewable energy is a central aim of the European Commission's energy policy. The Commission's White Paper for Community Strategy (European Commission 1997) sets out a strategy to double the share of renewable energies in gross domestic energy consumption in the European Union by 2010. The objective of the European directive on renewable origin electricity production is 21% of gross renewable origin consumption in 2010, which does not take into consideration hydroelectric production. The EU is supporting biofuels with the objectives of reducing greenhouse gas emissions, boosting the decarbonisation of transport fuels, diversifying fuel supply sources and developing long-term replacements for fossil oil. The development of biofuel production is also expected to offer new opportunities to diversify income and employment in rural areas. The Directive (2003/30/EC) on the promotion of the use of biofuels or other renewable fuels for transport sets the target of 5.75% share of biofuels in transport fuels by the end of 2010. The EU Strategy for Biofuels has three aims: first, to further promote biofuels in the EU and developing countries, ensure that their production and use is globally positive for the environment and that they contribute to the objectives of the Lisbon Strategy taking into account competitiveness considerations; second, to prepare for the large-scale use of biofuels by improving their cost-competitiveness through the optimised cultivation of dedicated feedstocks, research into "second generation" biofuels, and support for market penetration by scaling up demonstration projects and removing non-technical barriers; and third, to explore the opportunities for developing countries – including those affected by the reform of the EU sugar regime – for the production of biofuel feedstocks and biofuels, and to set out the role the EU could play in supporting the development of sustainable biofuel production (Commission of the European Communities 2006).

The changing regulations concerning the share of renewable energies and biofuels will also affect Finland, changing renewable energy production, such as field energy and wood. This could have implications for agricultural production and demand and price of agricultural land. If large amounts of wood from Finnish forests were used in energy production, there would be more competition for wood as a raw material, and this could affect supply and prices of wood as well. If most of the residuals after harvesting were collected for energy, there could be impacts to the nutrient budget of forests and possibly also nutrient leaching from forest lands.

Energy infrastructure, particularly electric power and oil production systems, are vulnerable to climate change impacts such as storms, increased precipitation, variable temperature and increased erosion. Climate change could increase combined ice and wind loads to power lines. Permafrost thawing in northern Russia can have impacts on gas and oil pipelines in the region and could cause breaks and disturbances in the supply. The reliability of energy supply is crucial for Finland and breaks in the supply can have serious and costly consequences nationally (Kirkinen et al. 2005; Mills 2007).

Hydropower production in Fennoscandia can be impacted by climate change, which is expected to change the seasonal distribution of annual precipitation, snowmelt and inflow to hydro reservoirs. Reservoir regulation guidelines may have to be modified. Dam safety is also crucial if the seasonal distribution of inflow to the reservoirs changes. Hydropower production potential is expected to increase in Sweden and Norway due to climate change. In Sweden, studies project increases in production of between 15 and 40% (Bergström et al. 2003; Lundahl 1995).

Transport

Arctic sea ice has been declining in both thickness and extent. The thawing is expected to continue in the future (IPCC 2007b; UNEP 2007) and could open the Northwest Passage and Northern Sea Route for marine transport (cf. Figure 18)[21]. The Northern Sea Route can reduce marine transit distances between Europe and Japan and northeast Asia by 50%. It also provides access to the Russian Arctic for oil, gas and other natural resources. Present day navigability varies inter-annually from less than a few weeks to more than a month.

The Northwest Passage is a sea route that connects the Atlantic and Pacific Oceans through the Canadian Arctic Archipelago. In the past the Northwest Passage has been virtually impassable because it is covered by thick, year-round sea ice. The potential benefits of a clear Northwest Passage are significant. Ship routes from Europe to Japan, China and other eastern destinations would be 4000 kilometres shorter. Oil produced in Alaska could move quickly by ship to eastern North American and European markets. The vast mineral resources of the Canadian North will be much easier and economical to develop.

Both the Northwest Passage and Northern Sea Route have large implications for commercial activity. Substantial savings in transportation costs can be expected each year, as well as savings in time and energy costs.. There is also a military and strategic dimension to the opening of new sea routes, which could alter the world's strategic balance.

For Finland, the opening of the Arctic Sea routes could mean increased transportation through Northern Finland and Lapland and possibly also changes in marine transportation in the Bothnian Bay or in the Baltic Sea in general.

6.2. Finland's foreign trade and investments

Finnish imports and exports from major world regions and groupings are shown in Table 13. Most of Finland's imports are from the OECD countries (69.2% of value of all imports in 2005, and 67.7% in 2006), and the EU accounted for 58.7% in 2005 and 55.6% in 2006. The share of developing countries in Finnish imports was 14.2% in 2005 and 16.6% in 2006. For exports, the EU share was also largest (56.8% in 2005 and 57% in 2006). Finland's exports to developing countries were 16 % in 2005 and 15.7% in 2006. Imports and exports of metal industry grew faster than total foreign trade in Finland. The share of metal industry products in total exports was 13.9% in 2006 (12.2% in 2005). Its share in total imports was 14.2% in 2006 (11.4% in 2005). The value of exports has risen more than the amount; the value of exports of copper, nickel, iron and steel, in particular, has increased. Almost half of metal industry imports were ore, ore concentrate and scrap metal. The most important export countries for metal industry products were Sweden, the Netherlands and Germany in 2006. The most important import countries in 2006 were Russia, Sweden, Germany, the Netherlands and Australia (National Board of Customs 2007b).

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[21] http://geology.com/articles/northwest-passage.shtml;
http://maps.grida.no/go/graphic/arctic_sea_routes_northern_sea_route_and_northwest_passage;
http://acsys.npolar.no/meetings/final/abstracts/posters/Session_4/poster_s4_170.pdf;
http://www.telegraph.co.uk/news/main.jhtml?xml=%2Fnews%2F2004%2F03%2F04%2Fwarct04.xml

Table 13 Finnish trade with selected regions in 2006 by Standard International Trade Classification (National Board of Customs).

2006	Total		EU		Euro zone		Rest of Europe	
January-December	Import	Export	Import	Export	Import	Export	Import	Export
	M e	M e	M e	M e	M e	M e	M e	M e
Total import/export	**55 253**	**61 489**	**30 699**	**35 035**	**17 413**	**18 326**	**10 518**	**10 057**
Food and live animals	**2 096**	**952**	**1 526**	**525**	**888**	**180**	**154**	**267**
Beverages and tobacco	**441**	**112**	**371**	**68**	**279**	**5**	**3**	**25**
Crude materials, inedible, except fuels	**5 317**	**3 703**	**2 235**	**2 312**	**1 406**	**1 488**	**1 213**	**240**
Cork and wood	834	1 611	214	970	14	551	586	45
Pulp and waste paper	160	1 253	42	926	10	715	13	93
Crude fertilizers and crude minerals	283	105	145	73	52	45	16	10
Metalliferous ores and metal scrap	3537	196	1 464	125	1 112	53	557	11
Mineral fuels etc	**8 473**	**3 192**	**1 755**	**2 288**	**232**	**751**	**6 051**	**220**
Coal, coke and briquettes	496	11	90	7	5	5	193	1
Petroleum and products	6 436	3 029	1 524	2 135	221	740	4 475	217
Gas, natural and manufactured	841	14	12	9	6	6	811	-
Electric current	700	139	129	137	-	-	571	2
Animal, vegetable oil, fat	**49**	**73**	**39**	**53**	**17**	**20**	**5**	**15**
Chemicals and related products, nes	**5 975**	**4 569**	**4 561**	**2 541**	**3 106**	**1 365**	**973**	**1 253**
Basic manufactures	**6 581**	**19 228**	**4 575**	**13 228**	**2 513**	**7 517**	**1 139**	**2 113**
Wood and cork manufactures	230	1 061	166	741	63	416	44	140
Paper, paperboard and articles	566	8 375	496	5 196	206	1 396	50	945
Non-metallic mineral manufactures	501	675	413	473	241	220	29	127
Iron and steel	1 898	4 679	1 400	3 817	756	2 088	293	400
Non-ferrous metals	1 211	2734	483	1 023	255	1 048	571	66
Machinery, transport equipment	**20 226**	**25 826**	**11 680**	**11 562**	**7 036**	**6 154**	**685**	**5 281**
Miscellaneous manufactured articles	**4 845**	**3 046**	**2 799**	**1 707**	**1 363**	**635**	**284**	**622**
Goods not classified elsewhere	**1 248**	**788**	**1 159**	**751**	**573**	**210**	**12**	**20**

Table 13 *continued*

2006	Total		OECD		External trade		Developing countries	
January-December	Import	Export	Import	Export	Import	Export	Import	Export
	M e	M e	M e	M e	M e	M e	M e	M e
Total import/export	**55 253**	**61 489**	**37 399**	**41 841**	**24 554**	**26 454**	**9 147**	**9 632**
Food and live animals	**2 096**	**952**	**1 660**	**536**	**571**	**426**	**341**	**87**
Beverages and tobacco	**441**	**112**	**394**	**57**	**71**	**44**	**33**	**5**
Crude materials, inedible, except fuels	**5 317**	**3 703**	**3 090**	**2 795**	**3083**	**1 392**	**948**	**749**
Cork and wood	834	1 611	79	1 271	620	641	26	290
Pulp and waste paper	160	1 253	48	1 065	118	327	99	170
Crude fertilizers and crude minerals	283	105	214	73	137	32	62	20
Metalliferous ores and metal scrap	3 537	196	2 369	140	2 072	71	688	56
Mineral fuels etc	**8 473**	**3 192**	**2 908**	**2 923**	**6 718**	**904**	**381**	**40**
Coal, coke and briquettes	496	11	232	10	406	3	50	1
Petroleum and products	6 436	3 029	2 299	2 767	4 912	894	313	34
Gas, natural and manufactured	841	14	53	8	829	5	18	5
Electric current	700	139	324	139	571	2	-	-
Animal, vegetable oil, fat	**49**	**73**	**42**	**64**	**10**	**20**	**5**	**4**
Chemicals and related products, nes	**5 975**	**4 569**	**5 242**	**3 073**	**1 414**	**2 029**	**119**	**379**
Basic manufactures	**6 581**	**19 228**	**4 922**	**15 582**	**2 006**	**5 999**	**653**	**1 888**
Wood and cork manufactures	230	1 061	122	969	64	320	18	48
Paper, paperboard and articles	566	8 375	509	6 678	69	3 178	12	1 019
Non-metallic mineral manufactures	501	675	424	490	89	202	40	28
Iron and steel	1 898	4 679	1 487	4 077	498	863	175	306
Non-ferrous metals	1 211	2734	621	2 254	728	710	101	362
Machinery, transport equipmt	**20 226**	**25 826**	**14 810**	**14 177**	**8 546**	**14 264**	**5 324**	**6 188**
Miscellaneous manufactured articles	**4 845**	**3 046**	**3 199**	**2 110**	**2 046**	**1 340**	**1 298**	**275**
Goods not classified elsewhere	**1 248**	**788**	**1 132**	**526**	**90**	**37**	**45**	**17**

The share of forest industry products in total exports has decreased during the past years. In 2000, the share of forest products in total exports was 26%, but in 2005 about 20%. The value of forest industry exports has also decreased from 13 billion euro in 2000 to 10.6 billion euro in 2005. In 2005 Finland was the world's fifth largest exporter of forest industry products, accounting for 5.3% of global exports of forest industry products and 7% of paper and board.

Finnish imports and exports in 2005 and 2006 by countries, and by countries and activities, and goods in 2006 are presented in Table 14 and Table 15. Two thirds of exports were to EU countries, the most important being Germany and the United Kingdom in 2005. The value of paper and board and wood exports has decreased since 2000 (National Board of Customs 2006).

Table 14 Finnish imports/exports year 2005 by country (source: National Board of Customs) http://www.tulli.fi/fi/05_Ulkomaankauppatilastot/06_Tilastoja/03_Maatilastoja/index.jsp

Country	Import value billion €	Import share %	Country	Export value billion €	Export share %
Germany	7.03	14.9	Russia	5.74	11.0
Russia	6.56	13.9	Sweden	5.66	10.8
Sweden	4.97	10.6	Germany	5.57	10.6
China	2.82	6.0	United Kingdom	3.52	6.7
United Kingdom	2.10	4.5	USA	3.06	5.8
USA	1.97	4.2	Netherlands	2.53	4.8
Netherlands	1.88	4.0	France	1.80	3.4
France	1.70	3.6	Italy	1.62	3.1
Italy	1.67	3.6	China	1.56	3.0
Japan	1.54	3.3	Estonia	1.36	2.6
Denmark	1.49	3.2	Norway	1.32	2.5
Estonia	1.48	3.1	Spain	1.29	2.5
Norway	1.05	2.2	Denmark	1.24	2.4
Belgium	1.03	2.2	Belgium	1.23	2.3
Hungary	0.75	1.6	Arab Emirates	1.12	2.1
Spain	0.70	1.5	Poland	1.03	2.0
South Korea	0.69	1.5	Japan	0.88	1.7
Poland	0.60	1.3	Saudi Arabia	0.65	1.2
Austria	0.46	1.0	Turkey	0.62	1.2
Switzerland	0.46	1.0	Canada	0.55	1.0
Ireland	0.44	0.9	Switzerland	0.48	0.9
Taiwan	0.42	0.9	Australia	0.44	0.8
Brazil	0.41	0.9	Latvia	0.42	0.8
Czech Republic	0.37	0.8	South Korea	0.41	0.8
Australia	0.33	0.7	Austria	0.39	0.7
Turkey	0.31	0.7	South Africa	0.38	0.7
Malaysia	0.30	0.6	Hungary	0.35	0.7
Slovakia	0.27	0.6	Ireland	0.33	0.6
Canada	0.23	0.5	Hong Kong	0.33	0.6
Portugal	0.22	0.5	Chile	0.31	0,6

Table 15 Imports and exports in 2006 by countries according to magnitude: imports by countries of origin, exports by countries of destination (National Board of Customs)

Country	Import value billion €	Import share %	Country	Export value billion €	Export share %
Russia	7.77	14.1	Germany	6.95	11.3
Germany	7.67	13.9	Sweden	6.46	10.5
Sweden	5.42	9.8	Russia	6.22	10.1
China	4.11	7.4	USA	4.01	6.5
United Kingdom	2.65	4.8	United Kingdom	4.00	6.5
The Netherlands	2.44	4.4	Netherlands	3.16	5.1
USA	2.08	3.8	France	2.06	3.4
Italy	1.87	3.4	China	1.97	3.2
France	1.81	3.3	Italy	1.96	3.2
Denmark	1.74	3.1	Estonia	1.77	2.9
Norway	1.71	3.1	Norway	1.60	2.6
Japan	1.59	2.9	Spain	1.53	2.5
Estonia	1.27	2.3	Belgium	1.41	2.3
Belgium	1.20	2.2	Denmark	1.31	2.1
South Korea	0.88	1.6	Poland	1.25	2.0
Spain	0.80	1.5	Japan	1.01	1.6
Australia	0.71	1.3	Saudi Arabia	0.83	1.4
Poland	0.69	1.2	Arab Emirates	0.83	1.3
Ireland	0.66	1.2	Turkey	0.72	1.2
Brazil	0.58	1.1	Switzerland	0.67	1.1
Taiwan	0.57	1.0	South Africa	0.54	0.9
Austria	0.49	0.9	Canada	0.53	0.9
Switzerland	0.47	0.9	Austria	0.47	0.8
Hungary	0.43	0.8	Latvia	0.47	0.8
Czech Republic	0.39	0.7	Ukraine	0.46	0.8
Malaysia	0.37	0.7	Australia	0.43	0.7
Turkey	0.33	0.6	Brazil	0.43	0.7
Slovakia	0.33	0.6	Hungary	0.42	0.7
Canada	0.31	0.6	South Korea	0.39	0.6
Kazakhstan	0.30	0.5	Lithuania	0.37	0.6

Finland's trade with developing countries has grown during the past years and in 2006, both imports and exports were the largest ever Figure 26. The trade surplus also continued its diminishing trend. The reason for this was China's emergence as one of the main suppliers of goods to the Finnish market (National Board of Customs 2007a).

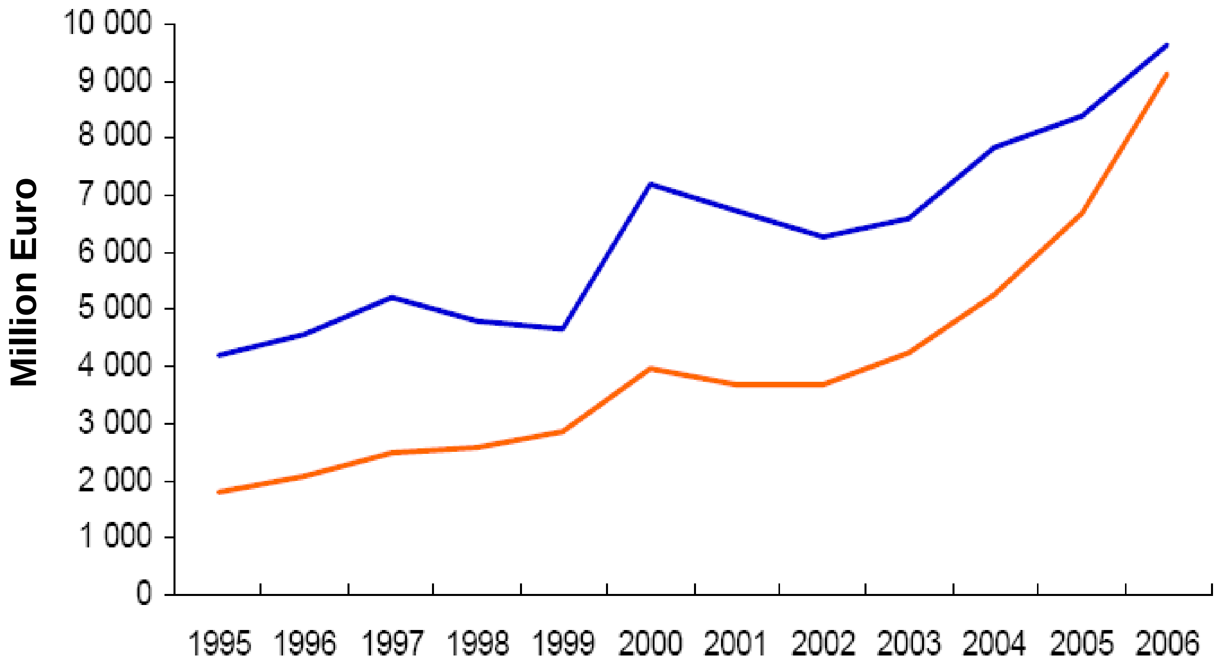

Figure 26 Trade between Finland and developing countries. Red line = imports, Blue line= exports. (National Board of Customs 2006)

Information of the foreign investments by Finnish companies is available from the Confederation of Finnish Industries EK, which carries out regular surveys on the subject (Table 16). The main Finnish foreign investments are by the forest, technology and chemical industries. The paper industry is responsible for most of the forestry investments, mainly to the EU and North America, but also to Asia and Latin America. Investments of technology industries have been more evenly distributed globally, however, the main part of investments have gone to the EU and Asia. Chemical industries have invested mainly in the EU but also in North America and Asia (EK 2007, 12).

Table 16 Investments of Finnish industry companies abroad 2001-2006, million euros. Source: Confederation of Finnish Industries (EK 2007).

	2001	**2002**	**2003**	**2004**	**2005**	**2006**
REGION	M e	M e	M e	M e	M e	M e
EU (excluding Finland)	4616	2330	1765	1779	1796	1490
North America	546	385	380	320	341	632
South and Central America	58	36	28	65	127	496
Russia	151	151	101	45	176	118
Asia	259	225	208	391	398	610
Others	209	66	23	33	15	3
Investments to foreign countries total	5839	3192	2505	2633	2854	3349

6.3. Economic impacts on Finland

Initially the impacts of climate change might not be very large in Finland due to the country's geographical location. At least in the near future, the adaptive capacity of Finland is also good, especially when compared to poorer countries. Perrels et al (2005) estimate that the economic aggregate impacts of climate change on Finland are probably rather modest and could even be slightly positive. Policies determine the extent to which benefits can actually be exploited and costs attenuated. Climate change-induced ups and downs in foreign trade are likely to be an important source of economic impacts for Finland. Effects can be mixed and benefits could occur in some periods and negative effects in others. However, extreme weather events could increase costs significantly.

In the Strategy for Economic Policy (2007, 63-64), the Ministry of Finance estimates that climate change mitigation will bring additional challenges to the Finnish economy. Significant mitigation levels would require large structural changes in Finland. Mitigation of greenhouse gas emissions would have larger impacts on the Finnish economy than in the EU on average. The Ministry of Finance also estimates that mitigation measures would lead to reduced production in Finland. If mitigation measures were gradual rather than abrupt, the impacts to the economy would be less. However, even with gradual measures the impacts on employment could be large. It would be important to enhance innovations, new technologies and education with government support.

However, there are also benefits as a consequence of climate policies. The benefits of mitigation policies could include avoided damages and ancillary advantages. Climate change policies can also create new employment, for example, through energy efficiency improvements and new technologies. Ancillary benefits include a reduction in the concentration of other harmful air pollutants in the atmosphere. This could lead to human health and ecosystem benefits. Climate mitigation that reduces dependence on fossil fuels for energy would also avoid costs associated with transport of fossil fuels about the globe. For example, oil pollution incidents and marine ecological disasters could be avoided. Significant benefits to energy security could also be achieved (OECD 2003, 85, 96-97; Commission of the European Communities 2007a, 29).

6.4. Migration and security issues

The rise in the number of victims of natural disasters over the past decade and the great levels of displacement caused by development projects have added millions to the number of forcibly displaced people in the world. According to the International Federation of the Red Cross and Red Crescent Societies, the total number of people affected by natural disasters has tripled over the past decade to 2 billion people, with the accumulated impact of natural disasters resulting in an average of 211 million people directly affected each year. This is approximately five times the number of people thought to have been affected by conflict over the past decade (UNHCR 2006).

The recent escalation in the numbers of those affected by disasters is understood to be due more to rising vulnerability to hazards than to an increase in the frequency of hazards per se. However, climate change could be playing a part in intensifying the number and severity of natural hazards. Displaced populations and other migrants are often disproportionately vulnerable to disasters because their normal livelihoods have already been disrupted or destroyed, or because their presence has contributed to environmental degradation in their areas of refuge. Where disasters occur in conflict zones, the destruction of infrastructure and lack of state services can seriously hamper the provision of relief and recovery assistance. "Self-settled" refugees and internally displaced persons living in urban areas are often highly vulnerable to the impact of natural disasters, as many live in informal and unsafe settlements where they have no legal entitlement to their homes and are not served by any risk-reduction measures (UNHCR 2006).

All those displaced by disasters have specific needs, including access to assistance, protection from violence, and the restoration of their livelihoods. The UN's Guiding Principles on Internal Displacement suggest that those uprooted by natural or man-made disasters are entitled to protection and assistance. However, this does not apply to those displaced by development policies and projects (UNHCR 2006, 27-28). It should also be noted that some areas may find themselves exposed to more favourable climates in the future than at present. It is conceivable that such areas might eventually attract migrants, maybe more than today.

There are also moral and legal questions concerning forced migrants. What are our responsibilities to environmental migrants, i.e. people who have been displaced by an environmental hazard? If climate change affects the distribution of benefits and damages among individuals or countries, potential and actual environmental migrants may have a claim on those who are better placed to deal with its actual or potential effects. It is also unjust to treat people as if they were merely citizens of an undifferentiated world and were not attached to particular environments. Therefore, the loss of homes and degradation or destruction of environments cannot be treated as nothing more than the loss of some substitutable natural resources. Instead, the development goals must be concerned with the protection of people's homes. At the very least, the substantive rights of people to have their homes protected should be supported by procedural rights to effective participation in global and national decisions that may significantly affect the conditions of their homes. Potential and actual environmental migrants should be entitled not only to equal rights to natural resources and wealth as citizens of the world but also as particular persons in a particular place they should be entitled to some control over what happens to their homes (Bell 2004, 138,152).

7. Finnish development co-operation

7.1. Goals of development co-operation

Finland currently has bilateral co-operation with the following countries: Ethiopia, Kenya, Mozambique, Tanzania and Zambia in East Africa; Nepal and Vietnam in Asia; and Nicaragua in Central America. Its bilateral policy is based on the partner countries' own development plans, and operates within the general goal of contributing to the eradication of extreme poverty (Ministry of Foreign Affairs 2004). Activities that help to achieve the goal include prevention of environmental threats and promotion of equality, human rights, democracy and good governance. Finland is committed to the principles of sustainable development in its development policy and to the values and goals of the UN Millennium Declaration. Finnish development policy is based on the principle of respect for the integrity and responsibility of developing countries. The states themselves bear responsibility for their own development and Finland's supports each country's own efforts.

7.2. Vulnerability of development co-operation partners in Africa

Finland's development co-operation partners in Africa are situated in East Africa, which is one of the regions that is likely to be adversely affected by climate change. The regions in Africa that are likely to face negative impacts include the mixed arid-semiarid systems in the Sahel, arid-semiarid rangeland systems in parts of eastern Africa, the systems in the Great Lakes region and the coastal regions of eastern Africa. Adverse impacts include increased water resources stress and impacts on agriculture and food security (e.g. see Figure 27; Thornton et al. 2006; IPCC 2007b).

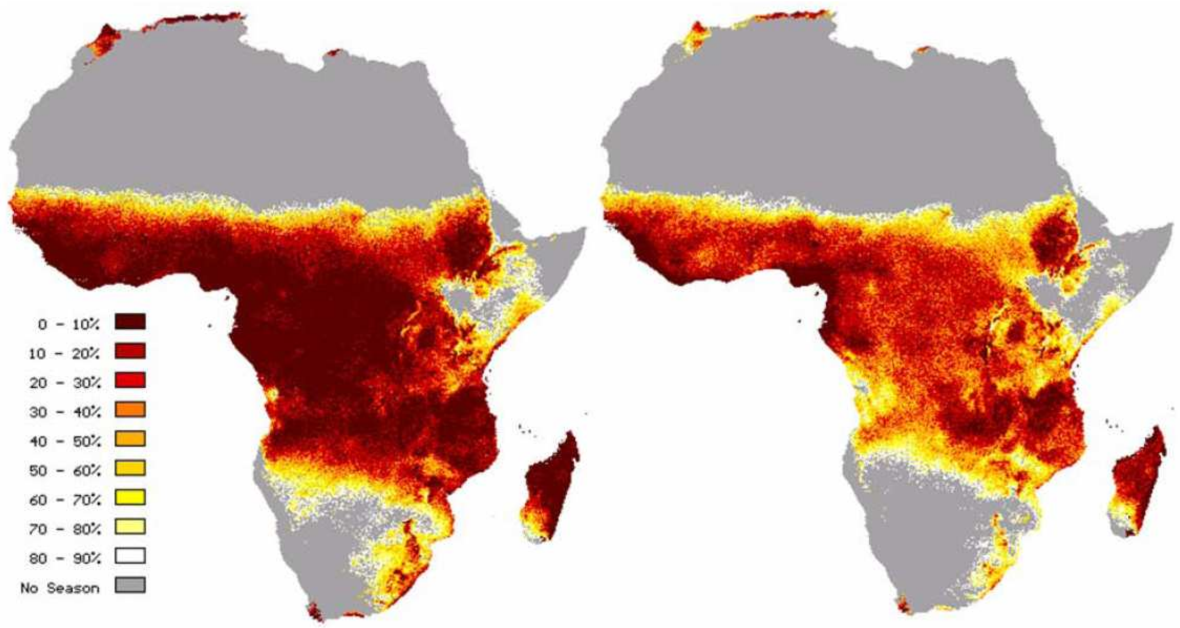

Figure 27 The probability of man season crop failure for current conditions (left) and under the HadCM3 climate (A1 emissions scenario) for 2050 (right). This is a relatively conservative assessment for crops, and does not include pastures (Thornton et al. 2006).

The following sub-sections provide descriptions of the major vulnerabilities to climate change characterising Finland's bilateral partners in Africa.

Ethiopia

About 75% of the population of Ethiopia is dependent on agriculture, which is almost entirely rainfed and small scale. Coffee and flowers are the only major commercial crops. A further 10% of the population earn their living entirely from livestock. Both farmers and pastoralists are highly dependent on climate for their livelihoods and this is reflected in the way the GDP of the country fluctuates with rainfall (IRI 2007, 31).

Table 17 Ethiopia: key statistics and vulnerabilities[22]

Land area (t km^2)	1 104 000
Population (2006)	79 289 000
Men/100 women	99
Annual population growth rate (2005 – 2006)	2.44
GDP per capita $ PPP valuation (2005/06)	794
Life expectancy (2006)	48.3
Illiteracy rate (2006)	53.7
Key vulnerabilities and impacts of climate change	▪ Possible increase in water resources stress ▪ Reduction in length of growing period in arid and semi-arid agriculture areas ▪ In highlands, growing season may lengthen

Ethiopia is located in the tropics, and topography plays a significant role in moderating temperature, with higher elevations experiencing weather typical of temperate zones[23]. Areas of lower elevation on the other hand experience climatic conditions typical of tropical savanna or desert. Average annual temperature in the highlands is about 16°C, while the lowlands average temperature is about 28°C. There are three seasons in Ethiopia. From September to February is the long dry season known as the bega; this is followed by a short rainy season, the belg, in March and April. May is a hot and dry month preceding the long rainy season (kremt) in June, July, and August. The lowest temperatures generally occur in December or January (bega) and the highest in March, April, or May (belg). However, in many localities July has the coolest temperatures because of the moderating influence of rainfall.

Ethiopia can be divided into four rainfall regimes. Within the main agricultural crop-producing areas, annual rains are expected in two seasons. The short rains usually fall in February – May and the main rains usually are in June-September. Ploughing and planting of short-cycle crops are dependent on the short rains. Short-cycle crops account for 7-10% of national crop production. If the short rains last long enough, it is also a potential time for sowing the main food crops millet, maize and sorghum, which will be harvested in October-December. More often though the main food crops are sown at the outset of the long rains. Short rains are also important for regeneration of pastures for livestock. The failure of short rains can have serious impacts for food security and the consequences get even more serious when the long rains fail or are greatly reduced (IRI 2007, 32).

The eastern and northern parts of the country are the most vulnerable to droughts while the west usually receives more reliable rains. When rainfall failures occur, Ethiopia is unable to meet its food

[22] Sources: OECD 2007; United Nations 2007; IPCC 2007b, Chapter 9; Arnell 2004; Thornton et al. 2006; National communication of Ethiopia (2001); World Bank Development Index
[23] http://www.britannica.com/eb/article-37682/Ethiopia

needs and is dependent on food aid. There are also population groups in Ethiopia that are chronically food insecure, the very poor who have limited livelihood options even in good climatic conditions (IRI 2007, 32-33). Figure 28 summarises projected changes in seasonal temperature and precipitation in Ethiopia during the 21st century from global climate models.

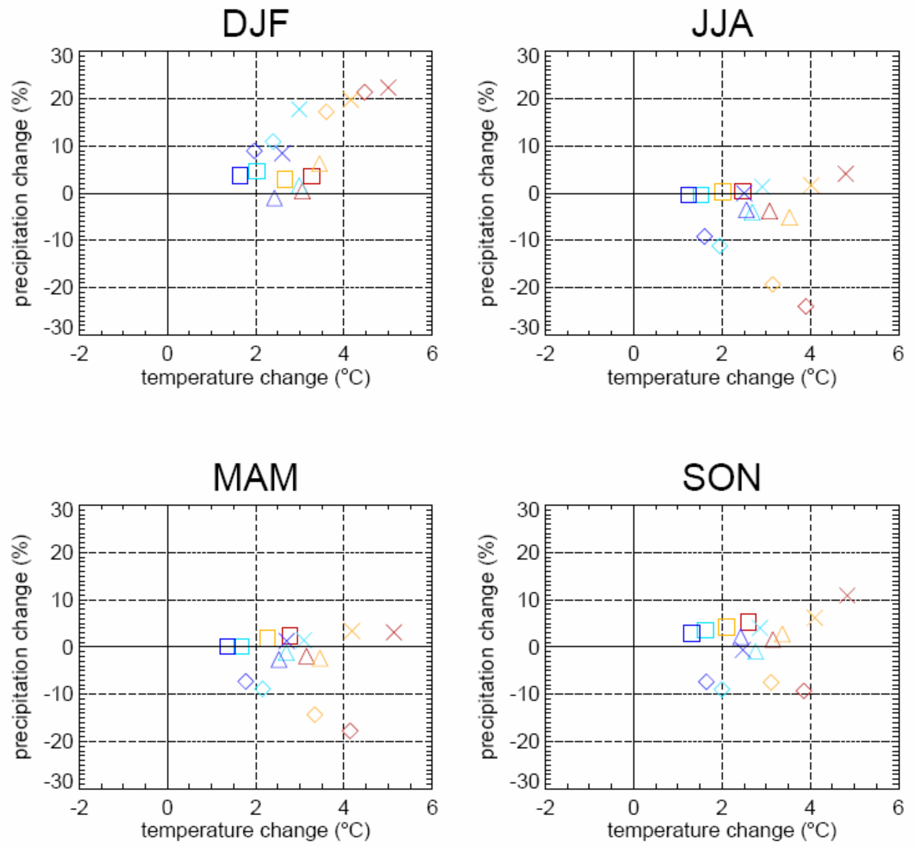

Figure 28 Ethiopia: projected changes in mean seasonal temperature (°C) and precipitation (percent) between the end of the 20th (1961-90) and the 21st (2070-99) centuries from four climate models (symbols): ◊ CGCM2 (Canada); Δ CSIROmk2 (Australia); □ DOE PCM (USA); x HadCM3 (UK), for four emissions scenarios (colours): A1FI – dark brown, A2 – light brown, B2 – light blue, B1 – dark blue. Seasons: DJF=December-February, MAM=March-May, JJA=June-August; SON=September-November. Sources: Mitchell et al. 2002; http://www.cru.uea.ac.uk/%7Etimm/climate/ateam/TYN_CY_3_0.html

The main environmental problems in Ethiopia are soil erosion, deforestation, recurring droughts, desertification, loss of biodiversity, and land degradation as a result of over cultivation and over grazing. Climate change is expected to have significant implications for Ethiopia, exacerbating existing environmental problems. The economy of the country depends largely on agriculture, which is very sensitive to climate variations. A large part of the country is arid and semiarid and is highly prone to desertification and drought. Ethiopia also has a fragile highland ecosystem, which is currently under stress due to population pressure. National forest, water and biodiversity resources are climate sensitive, and Ethiopia is also affected by vector-born diseases, such as malaria, that are associated with climatic variations (Initial National Communication of Ethiopia 2001).

Under a range of SRES scenarios, many parts of sub-Saharan Africa are likely to experience a decrease in the length of the growing season, which may be severe in some areas. This is due to projected increases in temperature and changes in rainfall patterns and amount. There are also a few areas in the highlands where the combination of increased temperatures and rainfall changes may lead to an extension of the growing season (Thornton et al 2006).

Model estimates indicate a shortening of the period to crop maturity in wheat of 10.6% to 18.5% under climate change scenarios. A decrease in maturity period by about 14-16% at Debrezeit and 17-19% at Kulumsa and Addis Ababa is estimated, with associated declines in yield. For sorghum, models predict consistent increases in potential grain yield, above ground biomass and nitrogen uptake. The average sorghum grain yield (1.58 t ha-1) predicted was similar to the long-term average (1.4 t ha-1) reported for the Nazareth area (Initial National Communication of Ethiopia 2001).

The lowlands in the northeast, southeast, east, south and southwestern parts of the country also referred to as rangelands (below 1500 metres of elevation) cover about 61-65 % of the total land area of the country. About 12% of the population lives there, and about 26% of the livestock population. About 93% of the people in these areas are pastoralists and agro-pastoralists. The lowlands are rich in natural resources, including a diversity of flora and fauna, and national parks and wildlife sanctuaries are situated there, as well as cultural heritage sites. The highlands are an important grazing area. From the estimated feed requirement, 15-50% comes from the highlands in the form of crop residues and fallow grazing (Wondwossen and Abay 1996; Initial National Communication of Ethiopia 2001).

Livestock in the lowlands depends on extensive grazing lands. In addition to the socio-economic constraints and inadequate attention to traditional resource management, recurrent drought over the area has become an important issue. The lowlands are normally low-rainfall areas and droughts frequently occur there. Depletion of pasture and water availability has been a key limiting factor for livestock production. Other factors include declining per capita livestock holdings and reduced production and productivity of the livestock (Initial National Communication of Ethiopia 2001)

Climate change could affect the grassland and livestock sector in many ways. Pasture productivity can change in quantity and quality, livestock productivity can change as well as distribution and incidence of animal and plant disease. Current climate variability and drought are already major challenges for this sector, and biodiversity in the area is in jeopardy. The impacts of climate change and compounded effects would combine to exacerbate this vulnerability (Initial National Communication of Ethiopia 2001).

Under climate scenarios, changes of forests from one type to another, shifting of forests from old to new habitat, reduction of area of forest coverage, fragmentation of forest zones, disappearance of mountain and lower mountain wet forest and sub-tropical desert scrub are expected (Negash 2000 in Initial National Communication 2001). Also appearance of tropical moist forest and expansion of tropical dry and very dry forests are projected. Under a scenario of 2.4 - 3ºC mean annual warming and a rainfall decline of about 5%, an expansion of tropical desert scrub and tropical dry and very dry forests and a shrinkage of lower mountain moist forest in the northern parts of the country are expected (Initial National Communication of Ethiopia 2001).

The Awash river originates in the central highlands and ends in Lake Abe on the Ethiopia - Djibouti border. The river is 1200km long and its catchment area is 113700km2. The river is highly vulnerable to climate change. Due to population pressure, there is already water stress in the area. Climate change could cause a considerable water deficit ranging from 10 to 33%. The Abay River starts in northwestern Ethiopia, joins the White Nile at Khartoum and drains into the Mediterranean. The basin of the river is highly sensitive to climate change. Runoff is projected to decrease, but models give a large range for the change (3-33%). Incremental scenarios were also employed in the study of the two basins. The results from the effect of the prescribed climate change scenarios indicate that runoff decreases significantly in warmer and drier scenarios over the two basins. Even a temperature increase of 2ºC alone, without precipitation change, would result in a significant decrease in runoff. An increase in precipitation could, however, offset the effects of temperature increase (Initial National Communication of Ethiopia 2001).

Kenya

Kenya has a great diversity of landforms ranging from the central highlands (with its highest point, Mt. Kenya, at 5199m) to low plains, bisected by the Great Rift Valley, with fertile plateaux to the west. The country has seven major agro-ecological zones, of which 80% is arid and semi-arid land. However, the Kenyan highlands comprise a very successful agricultural production system Three quarters of the population is sustained on 17 % of agricultural land that has high quality soils and receives enough rainfall (Osbahr and Viner 2006; Thornton et al. 2006).

Table 18 Kenya: key statistics and vulnerabilities[24]

Land area (km^2)	570 000
Population (2006)	35 106 000
Men/100 women	100
Annual population growth rate (2005 – 2006)	2.20
GDP per capita $ PPP valuation (2005/06)	1 835
Life expectancy (2006)	49.6
Illiteracy rate (2006)	26.4
Key vulnerabilities and impacts of climate change	▪ Increased risk of water resources stress ▪ Increased risks of droughts and floods ▪ Possibility of increase of malaria in the highlands ▪ Close to 50% of glaciers on Mount Kenya have already disappeared – continued loss of glaciers will have impacts on mountain ecosystems and tourism ▪ Increased risk of wild fires

Kenya has limited natural resources, especially water, minerals and agricultural land. Weather related hazards also present a serious threat to the socio-economic development of the country. Vulnerabilities in the country include inequitable patterns of land ownership, high population growth rate, rural-urban migration of the population, poorly planned urbanisation, deforestation, and high levels of unemployment. Increasing poverty and high food prices greatly reduces the resilience of Kenyans to disasters. There are high levels of both rural-urban and rural-rural migration, especially in the arid and semi-arid regions, which under drought can become vulnerable to environmental degradation. While agriculture is the main sector of the Kenyan economy, livestock production is central to livelihoods and food security of the people in the arid and semi-arid regions. A large number of the poor depend on subsistence agriculture, pastoralism or employment in the urban informal sector. Food insecurity is a major problem, with high malnutrition rates especially in the arid and semi-arid regions. In addition, up to 2-5 million people can quickly become dependent on aid relief during major droughts. Traditionally, the eastern plateau and pastoral areas in the north and south have been worst affected by drought. These problems have been exacerbated by refugees related to armed conflict in neighbouring countries in the Horn of Africa region. Increased population and sedentary lifestyles have made pastoralists

[24] Sources: OECD 2007; United Nations 2007; IPCC 2007b; Thornton et al. 2006; Watson et al. 1998; UNEP 2007; World Bank Development Index

more vulnerable to climate variability because grazing lands are settled or remain classified as protected areas. The most affected groups of people by natural hazards are the poorer sectors of the population living in slums and squatting along flood-prone and landslide areas (Wakabi, 2006) (Barrett et al., 2001; Ellis and Freeman, 2004) (Lennié et al., 2005) (Osbahr and Viner 2006, 3-4).

Kenya’s climate varies from a humid tropical climate along the coast to arid areas inland. Mean annual temperature varies considerably with elevation (27°C at the coast and decreasing with altitude). Seasonal differences are characterised according to rainfall rather than temperature. Kenya's rainfall is bi-modal, with two rainy periods: long rains from March to May and short rains from October to December. Rainfall is correlated to topography (the highest elevation regions receive 1800mm per year whilst the low plateau receives only 320 mm). Over two-thirds of the country receives less than 500 mm of rainfall per year and 79% has less than 700 mm per year. Over the last 50 years rainfall means have been decreasing inland and increasing on the coast (Oshbar and Viner 2006, 4; OECD 2003, Thornton et al. 2006).

Natural disasters are an integral part of Kenyan climate, with significant variability from year to year. Dry seasons can experience significant rainfall whilst wet seasons can often fail completely. Rainy seasons in Kenya can be extremely wet and often late or sudden, bringing floods and inundation. Major floods periodically afflict the Winam Gulf of Lake Victoria, the Lower Tana basin and the coastal regions. It is commonly perceived in Kenya that a large proportion of rainfall variability is attributable to El Niño. However, there is currently no clear relationship between either El Niño or La Niña events and prolonged drought or particularly wet periods (Usher, 2000). (Osbahr and Viner 2006, 4-5).

Kenya is heavily dependent on agriculture and natural resources, and it is on these that Kenya’s unpredictable rainfall patterns have the most detrimental impact. The long droughts that occur when wet seasons fail, sometimes for consecutive years, can cause drying of water sources, famine and hardship, and widespread disease as the poor nutrition reduces resistance to illness (Osbahr and Viner 2006, 6).

Figure 29 summarises projected changes in seasonal temperature and precipitation in Kenya during the 21st century from global climate models. For East Africa, climate model simulations under a range of possible emissions scenarios suggest temperature increases of around 2.5- 3°C by the end of the century, but with the possibility that this may be as high as 5°C. Rainfall projections are less certain, with a range of models and scenarios suggesting both increases and decreases in total precipitation. For September-May, most models project increases in total rainfall of up to 30 %. Changes in rainfall during the rest of the year are less clear and rainfall may increase or decrease by as much as 20 % between June and August. The region from Lake Victoria to the central highlands east of the Rift Valley are likely to experience increases in annual rainfall, and regions in the arid east and north experience decreases.

The IPCC (2001) projects that in the 21st century, increases in temperatures would significantly impact on water availability, and thus exacerbate the drought conditions already regularly experienced and predicted to continue. The unpredictability of Kenya’s rainfall and the tendency for it to fall heavily during short periods are also likely to cause problems by increasing the occurrences of heavy rainfall periods and flooding. Other trends, such as changes in lake levels and the melting of the Lewis glacier on Mount Kenya, are also likely to accelerate (Osbahr and Viner 2006, 8-9).

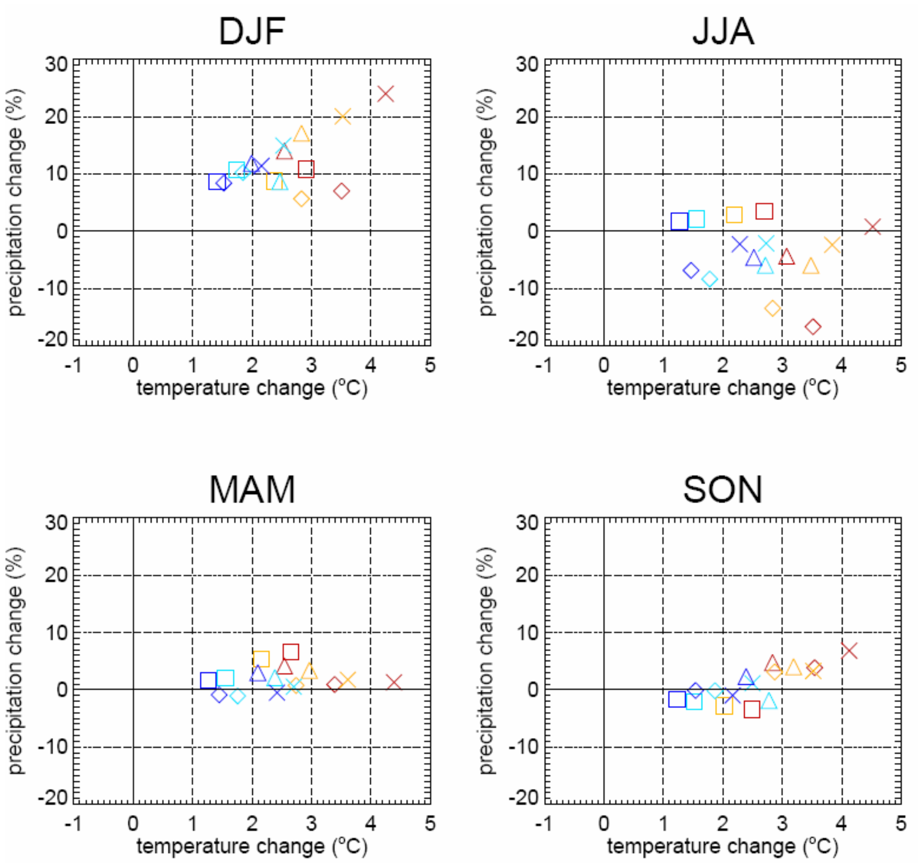

Figure 29 Kenya: projected changes in mean seasonal temperature (°C) and precipitation (percent) between the end of the 20th (1961-90) and the 21st (2070-99) centuries from four climate models (symbols): ◊ CGCM2 (Canada); Δ CSIROmk2 (Australia); □ DOE PCM (USA); x HadCM3 (UK), for four emissions scenarios (colours): A1FI – dark brown, A2 – light brown, B2 – light blue, B1 – dark blue. Seasons: DJF=December-February, MAM=March-May, JJA=June-August; SON=September-November. Sources: Mitchell et al. 2002; http://www.cru.uea.ac.uk/%7Etimm/climate/ateam/TYN_CY_3_0.html

Under Kenya's current (2002-2005) population growth rate of around 2.2 percent (UN 2006), pressure on land and water is likely to be greater in the future, and may lead to an escalation in conflict between different users. More variable and intense drought spells may bring widespread famine, food insecurity and soil erosion to areas where inappropriate farming techniques and deforestation have been practiced (Marcoux, 1998). This has the potential to make pastoral livelihoods in the arid and semi-arid regions unviable, as well as significantly damage the production of export crops. Vulnerability to disease can be expected with malnutrition. Increases in flooding, landslides and water pollution are likely to cause loss of life, property and infrastructure, and repeat outbreaks of diseases such as Rift Valley Fever, malaria and cholera, with children especially vulnerable. Increases in intensity, variability and frequency of flooding and drought events will reduce the country's long-term ability to recover between events and endanger the development progress unless adaptation strategies are implemented. For example, the efficiency of hydroelectric energy supply, economic development and reservoirs and roads will be vulnerable (Osbahr and Viner 2006, 9).

Kenya is not well-endowed with water resources. Its annual surface-water and ground-water potential is less than 600 m^3 per capita and well below the value of 1000m^3 per capita, which demarcates a situation of water scarcity. Factors threatening the water sources include: frequent droughts and floods, rapid population growth, which leads to the destruction of water-catchment areas through land conversion and fragmentation; pollution from chemical pesticides and fertilizers on agricultural land, as well as industrial wastes and raw sewage leaching into surface and ground water (OECD 2003, 310).

Rangelands in Kenya are already experiencing high climatic variability and frequent drought events. They are very susceptible to rapid environmental degeneration due to climatic factors and human land use. In dry parts of eastern Africa, cultivation of rangelands is uncommon and occurs mainly where irrigation is possible or where water can otherwise be sequestered and stored for cropping. Rainfall is bimodal in most east African rangelands, resulting in two plant growing seasons. In northern Kenya, the best years for livestock production are those in which moderate rainfall extends over several months, resulting in a long period of foliage production and livestock milk production. The distribution and timing are as important as total annual amounts of rainfall for rangelands (Watson et al. 1998, 43).

Mozambique

Mozambique is one of the poorest countries in the world, with over 50% of its population living in extreme poverty. Development has been heavily compromised in recent years by civil war, border conflicts, HIV/AIDS and extreme climate events. During 1980-2007 there were seven major floods and seven major droughts in the country. About 80% of Mozambique's population works in agriculture and fisheries that are highly vulnerable to climate variability and extremes. Most of the people also live at subsistence level. Mozambique is primarily a low-lying coastal country with an arid or semi-arid climate, which makes it vulnerable to climate change (IRI 2007, 15-16, Mozambique Initial National Communication 2003).

Table 19 Mozambique: key statistics and vulnerabilities[25]

Land area (km^2)	802 000
Population (2006)	20 158 000
Men/100 women	94
Annual population growth rate (2005 – 2006)	2.00
GDP per capita $ PPP valuation (2005/06)	1 957
Life expectancy (2006)	41.8
Illiteracy rate (2006)	48.3
Key vulnerabilities and impacts of climate change	▪ Coastal areas vulnerable to sea level rise and tropical cyclones ▪ Increased risks of droughts and floods ▪ Agriculture and forestry negatively affected ▪ Possible advantages to pastures as foliage area expected to increase

Mozambique lies largely within the tropics, and much of the coastline is subject to the regular seasonal influence of the Indian Ocean monsoon rains[26]. The monsoon influence is strongest in the northeast but is modified somewhat in the south by the island barriers of Madagascar**,** the Comoros, and the Seychelles. With the exception of highland areas on the northern and western borders and around Gurue (east of the Malawi protrusion into Mozambique), where elevation modifies both

[25] Sources: OECD 2007; United Nations 2007; IPCC 2007b, Chapter 9; Arnell 2004; Thornton et al. 2006, National communication of Mozambique (2003);
http://www.climatecentre.org/downloads/File/preparing%20for%20climate%20change%20and%20disaster%20risk%20reduction%20in%20mozambiqe%20july%202006.pdf
[26] http://www.britannica.com/eb/article-43965/Mozambique

temperature and humidity, the climate is seasonal and tropical. Daily temperatures throughout the country average in the lower to mid-20s °C, with the highest temperatures occurring in October - February and the lowest in June and July. Uncomfortably warm average daily temperatures in the 30s °C are normal only in the upper Zambezi valley and along the northeastern coast, while cool temperatures below 20°C occur year-round only in the mountainous areas on the western borders.

The sharpest contrast in humidity and precipitation is between north and south. The entire region north of the Zambezi and east of the Shire River valley is humid and warm, as is the coastal plain in the south, while the southern interior and most of the Zambezi valley west of the Shire are quite dry; the south-central area is even considered semi-arid. Precipitation is greatest throughout the north and in the central region east of the Shire River, where it ranges between 1010 and 1780 mm; the highest precipitation is in the highlands and in coastal pockets around Beira and Quelimane. In the Zambezi valley west of the Shire, however, average precipitation declines to between 610 and 810 mm, whereas in the south, to the west of the coastal plain, average annual precipitation is only about 610mm. The semiarid southern regions receive only about 75 mm of precipitation per month in the wet season from November to February and almost none in the dry season between April and October. West-central and southern Mozambique are subject to periodic drought.

Mozambique's high incidence of flooding is explained by two factors. First, every year three to four of the tropical cyclones that form in the south-western Indian Ocean cause high winds and heavy rain in the coastal areas, leading to flooding. Second, Mozambique is situated downstream of nine major river systems that drain vast areas of southeastern Africa. Mozambique thus has to manage the downstream effects of rain that falls beyond its own catchment areas. Drought, floods and tropical cyclones happen all over the country, drought is more common in the southern areas, and floods happen more frequently in the central and southern regions. Tropical cyclones occur in the coastal zone (IRI 2007, 16; Mozambique Initial National Communication…2003).

Figure 30 summarises projected changes in seasonal temperature and precipitation in Mozambique during the 21st century from global climate models. Changes in average climate and increased occurrence of extreme events – tropical cyclones, floods and droughts – are projected to have significant implications for Mozambique. Droughts cause several adverse impacts such as loss of human and animal lives, loss of cultures, drying of water bodies, reduction of pastures, increase of prices of agricultural products, increased need of food import and international aid, appearance of diseases, and loss of biodiversity (Mozambique Initial National Communication, 2003).

Tropical cyclones bring high winds, torrential rains and storms that can cause floods, landslides, and erosion in the coastal area as well as in the interior of the country. Tropical cyclones can cause social and economic recession, losses of lives, human suffering, destruction of properties, degradation of the environment and severe disruption of normal activities (Mozambique Initial National Communication, 2003).

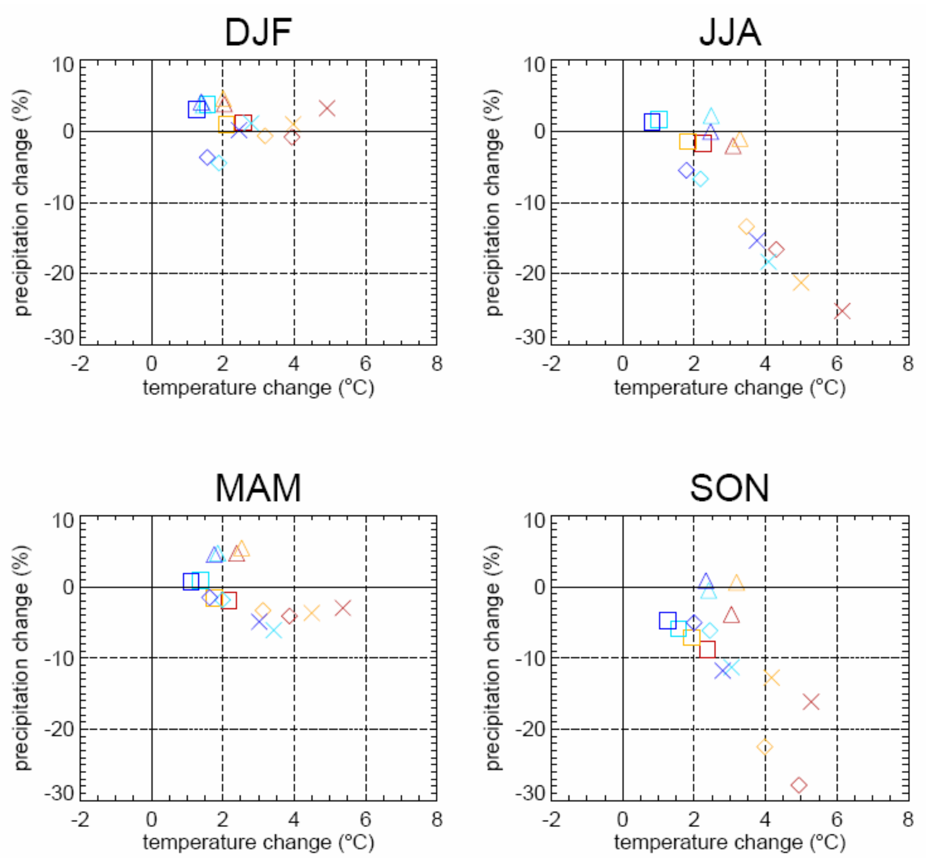

Figure 30 Mozambique: projected changes in mean seasonal temperature (°C) and precipitation (percent) between the end of the 20th (1961-90) and the 21st (2070-99) centuries from four climate models (symbols): ◊ CGCM2 (Canada); Δ CSIROmk2 (Australia); □ DOE PCM (USA); x HadCM3 (UK), for four emissions scenarios (colours): A1FI – dark brown, A2 – light brown, B2 – light blue, B1 – dark blue. Seasons: DJF= December-February, MAM=March-May, JJA=June-August; SON=September-November. Sources: Mitchell et al. 2002; http://www.cru.uea.ac.uk/%7Etimm/climate/ateam/TYN_CY_3_0.html

With climate change, the mean temperature is estimated to increase 1.8 - 3.1 ° C and the precipitation to decrease 2-11% according to different scenarios. The impact of climate change on water resources of Mozambique will be manifested through irregularities in temporal and spatial distribution of rainfall and by increases of temperature and solar radiation, which in turn will increase evaporation levels. The city of Beira, in central Mozambique, is estimated to be the most vulnerable site to the effects of sea level rise. Beira is the second largest city in Mozambique and a low-lying harbour town of strategic importance. It is also the nearest natural port for Malawi, Zambia, Zimbabwe and other land locked countries in Southern Africa (Mozambique Initial National Communication, 2003).

Agriculture is the most important sector for the Mozambican economy. North of the Save River, along the coastal areas, the climate is favourable for agriculture through most of the year, but the soil in certain areas is deficient. Most fertile lands can be found along river valleys. In the South, the soil is relatively fertile, but climatic conditions are a major hindrance due to the large annual variability of rainfall. Climate change can affect agricultural production in Mozambique through the resulting changes in temperature, rainfall, atmospheric humidity and radiation. Pastures seem to be the only sector with positive impacts, as an increase of the foliage area is projected. Conversely, reduction of the nutritional capacity due to the weak absorption of nitrogen would negatively counterbalance the predicted increase in pastures (Mozambique Initial National Communication, 2003).

Tanzania

Tanzania's climate ranges from tropical to temperate in the highlands. Average annual precipitation over the entire nation is 1042 mm. Average temperatures range is between 17°C and 27°C, depending on location. Natural hazards include both flooding and drought. Within the country, altitude plays a large role in determining rainfall patterns, with higher elevations receiving more precipitation. The total amount of rainfall in the country is not very large. Only about half the country receives more than 762 mm annually. Tanzania's precipitation is governed by two rainfall regimes. Bi-modal rainfall, comprised of the long rains between March-May and short rains between October-December, is the pattern for much of the northeastern, northwestern (Lake Victoria basin) and the northern parts of the coastal belt, similar to neighbouring Kenya (see above). A unimodal rainfall pattern, with most of the rainfall during December-April, is more typical of most of the southern, central, western, and southeastern parts of the country (Agrawala et al. 2003, 11-12).

Table 20 Tanzania: key statistics and vulnerabilities[27]

Land area (km^2)	945 000
Population (2006)	39 025 000
Men/100 women	
Annual population growth rate	1.8 (World Bank) / 2.9 (1988-2002)
GDP per capita $ PPP valuation (2005/06)	594
Life expectancy (2006)	46.5
Illiteracy rate (2006)	30.6
Key vulnerabilities and impacts of climate change	▪ Possible increase in water resources stress ▪ Possibility of droughts increases in some areas ▪ Maize yields are projected to decrease; largest decreases in central regions of Dodoma and Tabora ▪ Yields of cash crops (coffee) projected to increase ▪ Most of forests projected to shift to drier regimes ▪ Dar-es-Salaam region vulnerable to sea level rise ▪ Mt Kilimanjaro's ice gap could disappear by 2020, impacts on biodiversity, tourism and increased wild fire risk

Figure 31 summarises projected changes in seasonal temperature and precipitation in Tanzania during the 21st century from global climate models. Mean annual temperatures in Tanzania are projected to rise by between about 1 - 4.5º C by the end of the century, with somewhat higher increases over June-August and lower values for December-February. Precipitation over the whole country is projected by most models to increase up to 2100, although seasonal declines are more prevalent in model projections for June-August. However, country averaged values are of limited utility as the precipitation regimes across Tanzania vary considerably.

[27] Sources: OECD 2007; Argawal et al 2003; IPCC 2007b; Thornton et al 2006; http://www.tanzania.go.tz/ppu/demografic_situation.html

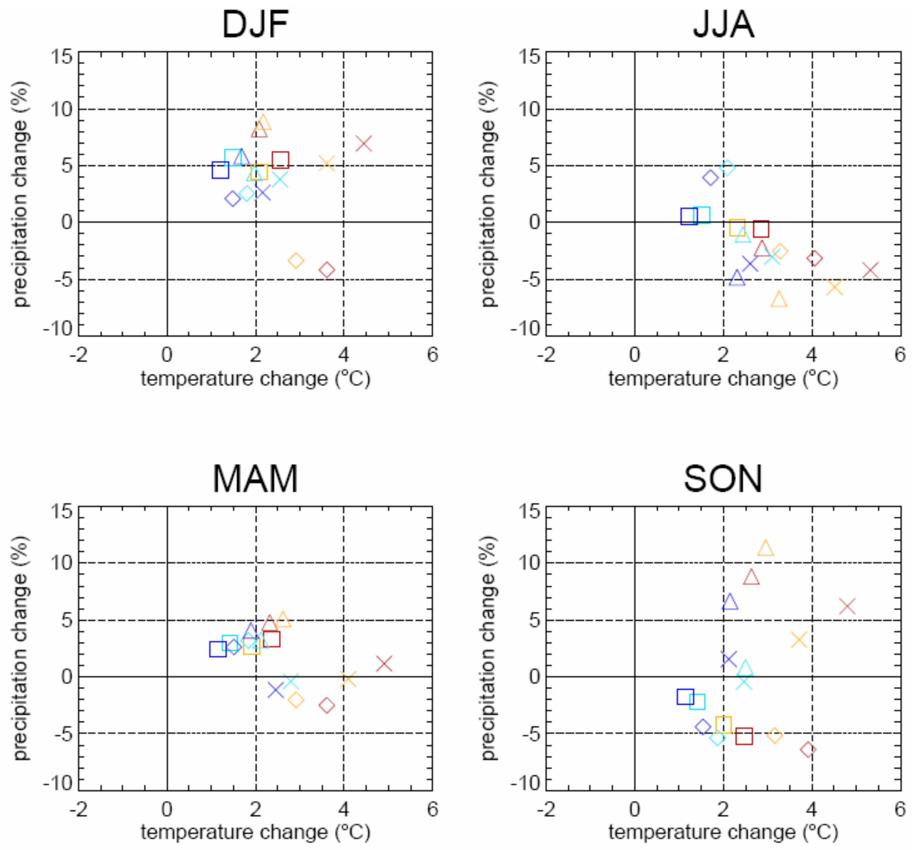

Figure 31 Tanzania: projected changes in mean seasonal temperature (°C) and precipitation (percent) between the end of the 20th (1961-90) and the 21st (2070-99) centuries from four climate models (symbols): ◊ CGCM2 (Canada); Δ CSIROmk2 (Australia); □ DOE PCM (USA); x HadCM3 (UK), for four emissions scenarios (colours): A1FI – dark brown, A2 – light brown, B2 – light blue, B1 – dark blue. Seasons: DJF=December-February, MAM=March-May, JJA=June-August; SON=September-November. Sources: Mitchell et al. 2002; http://www.cru.uea.ac.uk/%7Etimm/climate/ateam/TYN_CY_3_0.html

The Tanzania Initial National Communication (2003) offers greater regional specificity, but the results should be interpreted with caution as they rely on projections from one or two earlier climate model simulations. Under a scenario of doubling of carbon dioxide, some parts of Tanzania are projected to experience increases in annual rainfall, precipitation is projected to decline in other areas. However, the timing of these changes might vary from location to location. Northern and southeastern sectors of the country could experience an increase in rainfall ranging between 5% and 45%. The central, western, southwestern, southern, and eastern parts of the country might experience a decrease in rainfall of 10% to 15%. The southern highlands might similarly experience a decrease of 10%, which could alter the suitability of this area for maize cultivation. However, seasonal patterns in possible changes in rainfall could be complex. In the rainfall unimodal region, rainfall is projected to decrease by 0- 25% in central regions during October, November, and December, but increase by 15% in March, April, and May. The southeastern sector could get a 5 - 45% increase in rainfall during the first three months of the season and an increase of 10-15% during the last three months (Agrawala et al. 2003, 13-14).

Agriculture is the most important sector of the Tanzanian economy. It comprised 45 % of GDP in 2000 (World Bank, 2002). Upwards of 80% of the population of the country relies directly on agriculture for their livelihood. Only 3.3% of the cropland was irrigated in 1999 (World Bank, 2002). The three most important crops are: maize, coffee and cotton. Maize is a major food staple, coffee is a major cash crop grown in large plantations, and cotton is another cash crop grown largely by smallholder farmers. Model results suggest that climate change may significantly influence future maize yields in Tanzania. The average yield decrease for projected climate under doubled carbon dioxide over the entire country was 33%, but simulations produced decreases as high as 84% in the central regions of Dodoma and Tabora. Yields in the north eastern highlands decreased by 22% and in the Lake Victoria region by 17%. The southern highland areas of Mbeya and Songea were estimated to have decreases of 10-15%. These reductions are due mainly to increases in temperature that shorten the length of the growing season and to decreases in rainfall. Consequently, the continued reliance on maize as a staple crop over wide areas of the country could be at risk. The two cash crops on the other hand are projected to experience increases in yield (Tanzania Initial National Communication 2003). For Lyamunugu, located within an area of bimodal rainfall, coffee yields are expected to increase by 18%, and for Mbozi, where rainfall is unimodal, the coffee yield is expected to increase by 16%. However, the yield estimates depend critically on estimates of change in precipitation. The potential impacts of climate change on cotton production in Tanzania parallel those for coffee. The agriculture sector thus may have both negative and positive impacts that could partially offset each other. However, maize is a critical food crop and could require adaptation measures (Agrawala et al. 2003, 15).

Tanzania has about 338,000 km^2 under forest cover, which represents about 44% of the total land area. Forests are an important source of fuel wood and other products for large numbers of Tanzanians. Furthermore, many of Tanzania’s 43 threatened mammal species, 33 threatened bird species, and prodigious biodiversity depend on forests (World Bank 2002). Under climate change, most of the forests across Tanzania are projected to shift towards drier regimes: from subtropical dry forest, subtropical wet forest, and subtropical thorn woodland to tropical very dry forest, tropical dry forest, and small areas of tropical moist forest respectively (Tanzania Initial National Communication 2003). Much of this projected change in distribution is attributed to an increase in ambient temperatures and a decline in precipitation in forested regions of the country. In the Kilimanjaro region in addition to the glacier retreat and eventual disappearance of the ice cap, there might be major changes in the extent, distribution, and species composition of the forests on the mountain as a consequence of changes in fire regimes. There is indication that intensification of fire risk as a result of warmer and drier conditions might already be underway. Continued loss of the mountain forest belt (which collects a significant amount of water from fog entrapment) from fire intensification would lead to a significant reduction of water yields with serious regional implications, affecting sectors such as agriculture and livestock as well (Agrawala et al. 2003, 15-16).

Climate change is projected to have mixed consequences for Tanzania’s water-resources, specifically for the three major river basins: Ruvu, Pangani, and Rufiji. The Ruvu basin, of particular importance because it is upstream of Tanzania’s major population centre, Dar es Salaam, could experience a 10% decrease in runoff according to the Initial National Communication (2003). The Pangani basin supplies water to the Tanga, Kilimanjaro, and Arusha regions, supporting a number of economically important activities (sugar plantations, irrigation scheme, water supply, and power stations). For the Pagani River, there is some seasonal variation, and annual basin runoff is projected to decrease by an estimated 6% under a 2 x CO_2 scenario. However, runoff in the Kikuletwa River, also within the Pagani Basin, is projected to decrease in all months, with annual reductions of 9%. The Rufiji basin is a large catchment in the south, focused on the Great Ruaha River, which is economically important in part because of the hydropower it generates at Mtera Dam and Kidatu Dam. The national assessment of vulnerability and adaptation (Mwandosaya et al. 1998) projects increases in annual runoff of 5% and 11% at Mtera and Kidatu, respectively, most coming in the period from November to March. All these estimates however are based on scenarios from a single climate model, and should be interpreted with some caution. Real uncertainties exist concerning present and future withdrawals for irrigation, changed land use, and urbanization. Nevertheless, decreases in runoff could potentially have serious affects on the regions of Dar es Salaam, Morogoro, Tanga, Coast, and Kilimanjaro. Dar es Salaam might be particularly vulnerable because it is the largest industrial, commercial, and administrative city in Tanzania (Agrawala et al. 2003, 16).

There is a possibility of future water shortages in Tanzania. The population is projected to reach 59.8 million by 2025, which implies that the amount of water available per person will decline by about 45 per cent to 1 500 m^3 a head, below the 1 700 m^3 threshold. Climate change has meant that Tanzania has been receiving inadequate rainfall since 2001, which in turn has led to reductions of water levels in various catchments. Inadequacy of rainfall also means that not enough water can be harnessed in the major water reservoirs for electricity generation thus creating the twin problems of water and energy shortages in the country (OECD 2007).

The coastline of Tanzania is about 800 km long and the coastal zone varies in width from 20 km to 70 km gradually rising to a plateau. Tanzania has relatively limited coastal lowlands, but there are extensive coastal wetlands, some important cities (Dar es Salaam), a number of important islands (such as Zanzibar), and a delta — the Rufigi River (Mwaipopo 2001). The main coastal features include mangrove forests and swamps, coral reefs, sand and mudflats, tidal marshes, woodland, and sisal and cashew nut estates. Mangrove forests in particular represent an important economic resource for coastal people, supplying firewood and timber for the construction of fishing boats, and providing feeding, breeding, and nursery grounds for a number of fish species and a variety of insects, birds, and small animals. The highest densities of population that might be threatened are found near Dar es Salaam and the islands of Zanzibar and Pemba. The Initial National Communication of Tanzania (2003) considers scenarios of both 0.5 m and 1 m sea level rise over the next century. Total land-loss is estimated to be 247 km^2 and 494 km^2 for 0.5 and 1 meters of sea level rise respectively. According to this analysis, the Dar es Salaam region would be vulnerable with values of structures at risk estimated to total US$ 48 million for a 0.5 m sea level rise and US$82 million for a 1 m rise (Tanzania Initial National Communication 2003; Agrawala et al. 2003. 17).

Climate plays an important role in the geographical distribution and seasonal abundance of vector species that are responsible for the transmission of a number of human diseases. Changes in temperature, precipitation, humidity, and wind patterns will directly affect vector species' reproduction, development, and longevity. The distribution of vector borne diseases in the human population is also limited by temperature in many regions where the climate is too cold for parasite survival (Martens et al. 1999). Of the various vector borne diseases malaria in particular is a major public health concern in Tanzania and is endemic over most of the country. It accounts for 16.7% of all reported deaths in Tanzania and is one of the leading causes of morbidity in all regions, ranging from 24.4% in Rukwa regions to 48.9% in Dar es Salaam (Tanzania Initial National Communication 2003). The problem of malaria is getting worse because of growing parasite resistance to first line anti-malarial drugs and mosquito resistance to insecticides. Currently, many population centres are located in areas where malaria transmission is currently only epidemic or nonexistent, such as the central highlands (e.g., Mbeya, Njombe, Iringa, and Arusha) In a warmer climate, new areas might be open to seasonal or year-around transmission. The vulnerability of highland populations to an increase in the endemicity of transmission of malaria, or of any of Tanzania's population to climate change induced health risks, will depend strongly on the evolution of control methods and the ability of Tanzania to afford such measures (Tol and Dowlatabadi, 2002; Agrawala et al. 2003, 17).

A study of Tanzania's vulnerability to climate change was carried out by the OECD (Agrawal et al. 2003) and many of the projections described above are taken from this study. Tanzania regularly suffers from various climate-related hazards, including droughts that have substantial effects on economic performance and on poverty. Many development plans and projects have recognized this climate sensitivity, but few of the development plans and projects that were reviewed in the study had taken climate risks into account. Given that current climate risks are already being neglected, it comes as no surprise that climate change is often ignored even more. In the few cases where climate change received attention, the focus was on mitigation, rather than adaptation.

Several donor strategies recognize Tanzania’s dependence on favourable weather, and the linkages between poverty, drought, and food security. The factors identified as underlying the drought problem included weak institutional capacity in the sector, poor water resource management, and the dilapidated condition of the water schemes and distribution networks in the rural and urban areas resulting from the under-funding of maintenance and rehabilitation.

Tanzania’s vulnerability to climate-related disasters, due to natural and human factors was also highlighted in the study findings. Natural and man-made disasters have eroded the coping capacity of the vulnerable populations especially in drought-prone areas. Traditional coping strategies are breaking down as land pressure increases. Floods and droughts, epidemics and crop pests, environmental damage and economic instabilities, have all had their effects on people’s capacity to meet their basic needs and subsequently their ability to survive and pursue their development ambitions and potential. Despite these strong linkages between climate and economic performance, as well as the relationships between droughts, environmental degradation and poverty, none of the donor strategies even mentions climate change.

Zambia

Zambia is a landlocked country occupying a near central position on the southern African subcontinent. Although Zambia is tropical, the relatively high altitude of most parts of the country permits the production of temperate crops. Zambia has three main seasons: cool-dry (April-August), hot dry (August-November) and hot wet (November-April). Rainfall is concentrated over the five month period from November to March and varies from 700 mm in the south to 1500 mm in the north. Zambia's vegetation is mainly savanna dominated by small areas of miombo woodlands. The country has ample water resources comprising seven large lakes and four major rivers. Groundwater resources are also abundant in the Congo/Zaire and Zambesi river basins. Even though there is large irrigation potential, the majority of agricultural production is rainfed and based on small-scale, subsistence farming systems (about 80% of all farmers), combined with extensive livestock production, with farm holdings of less than nine hectares (Perret 2006, 1; Chigwada 2004, 13-17).

Zambia is divided into three main agro-ecological regions, which are defined on the basis of climatic characteristics of which rainfall is the dominant factor. The region of the Zambezi and Luangwa Valleys covering the southern part of the country, receives less than 800 mm of rain annually and temperature in this region varies from 20º to 25º C. It is the driest region in the country and is most prone to drought. The region that covers the central part of Zambia, extending from the east through to the west, receives between 800 mm to 1000 mm of rainfall. Temperatures range during the rainy season from 23º to 25ºC. The third region receives more than 1000 mm of rainfall in a season and covers the northern part of the country (Hewitson 2006, 4).

Table 21 Zambia: key statistics and vulnerabilities[28]

Land area (km^2)	752 620
Population (2006)	11 861 000
Men/100 women	100
Annual population growth rate (2005 – 2006)	1.73
GDP per capita $ PPP valuation (2005/06)	1 167
Life expectancy (2006)	38.8
Illiteracy rate (2006)	32
Key vulnerabilities and impacts of climate change	▪ Possible increase in water resources stress ▪ Possibility of increased droughts ▪ Decline in maize production ▪ Decrease in food security ▪ Increased risk of wild fires ▪ Adverse impacts to human health due to deteriorating water quality during floods and droughts, increase in vector-borne diseases

Zambia's rainfall is highly variable. Most rainy seasons in Zambia in the past twenty years have shown a tendency of drought. For a country that has more than 70% of its population relying on agriculture directly or indirectly, the impact of extreme weather events is critical. Annual total precipitation has generally decreased across most of the country for the period 1961 - 1990 except for the extreme south-eastern areas and some parts of the central watershed where there has been a slight increase. The most marked decrease of precipitation has occurred over the northern areas. For the monthly maximum consecutive 5-day precipitation, there has been a negative trend over the northern and southern areas and a positive trend over the central parts of the country (Hewitson 2004).

The number of days with maximum temperature above 25ºC has increased in most areas of Zambia, except for the northernmost areas and Kadoma where there is a decrease. The number of cold nights (percentage of days when daily minimum temperature is below the 10th percentile) has decreased in most areas. Cool days (percentage of days when daily maximum temperature is below the 10th percentile) have also significantly declined at most stations. Warm nights (percentage of days when daily minimum temperatures exceeded the 90th percentile) have increased across most of the country, and hot days (percentage of days when daily maximum temperature exceeds the 90th percentile) have increased in frequency at all stations. The diurnal temperature range has increased over most of the stations, but reduced over the eastern Highlands (Hewitson 2006, 4-5).

Figure 32 summarises projected changes in seasonal temperature and precipitation in Zambia during the 21st century from global climate models. Key climate change vulnerabilities in Zambia include increased water stress, reduced agricultural productivity and livestock, and adverse effects to health. A study on the risks related to climate change at the local level revealed a rise in the frequency and severity of extreme events, including droughts, floods and high temperatures, and a decrease in the length of the rainy season. Droughts and extreme heat events are widespread and are considered major climate hazards throughout the country. Heavy precipitation events are also widespread and increasing in frequency. They cause greatest damage in river valleys and floodplains (e.g. along the

[28] Sources: OECD 2007; United Nations 2007; IPCC 2007b; Thornton et al. 2006; Chigwada 2004

Zambezi river). The rise in extreme climatic events is leading to increased food insecurity and health issues. When facing climate hazards, small scale farmers (who are negatively affected by disruption of their normal farming cycles) rely heavily on access to alternative natural resources from forests and wetlands (Riché 2007).

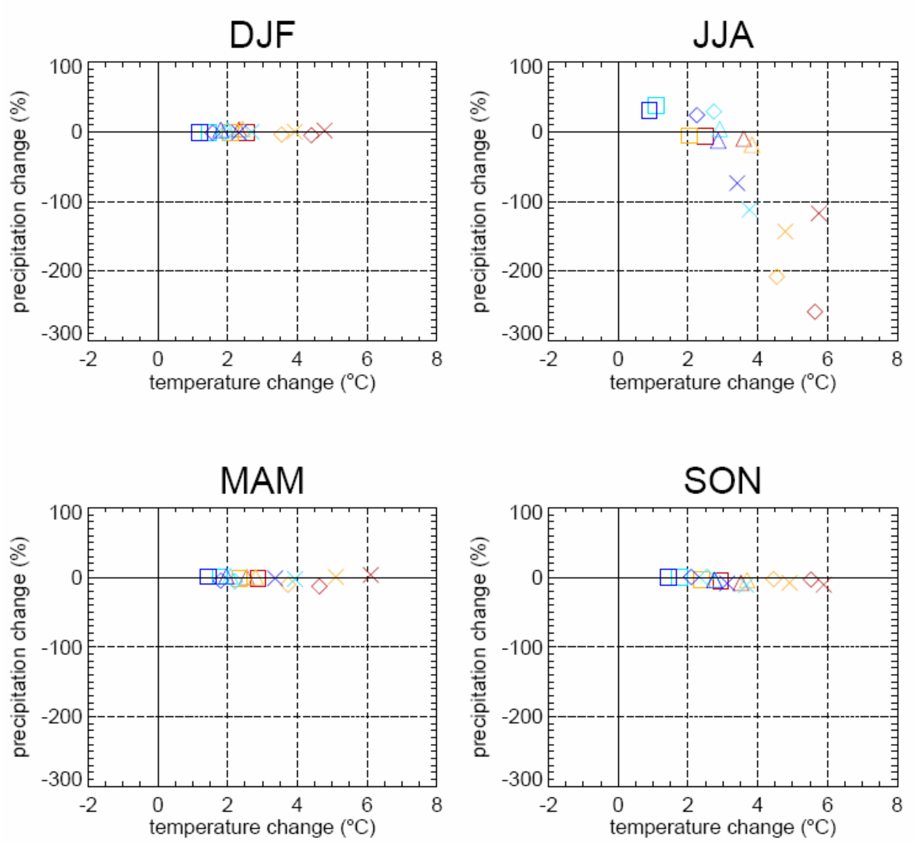

Figure 32 Zambia: projected changes in mean seasonal temperature (°C) and precipitation (percent) between the end of the 20th (1961-90) and the 21st (2070-99) centuries from four climate models (symbols): ◊ CGCM2 (Canada); Δ CSIROmk2 (Australia); □ DOE PCM (USA); x HadCM3 (UK), for four emissions scenarios (colours): A1FI – dark brown, A2 – light brown, B2 – light blue, B1 – dark blue. Seasons: DJF=December-February, MAM=March-May, JJA=June-August; SON=September-November. Sources: Mitchell et al. 2002; http://www.cru.uea.ac.uk/%7Etimm/climate/ateam/TYN_CY_3_0.html

The greatest reduction in runoff by 2050 in Africa is expected to be in the southern African region (Arnell 1999), thereby suggesting that changes in the water use to resource ratio will put countries in the "high water stress" category. Combining the shortfall in rainfall and the effect of increases in potential evaporation, the resultant reduction in run-off in the major river basins of the region, including Zambia, will be up to 40%. The precipitation in Zambia is uneven across the country and varies from year to year. Low soil moisture and high evapotranspiration will promote desertification because of a reduction in vegetation cover. This will lead to soil erosion and sediment discharge that could cause siltation of reservoirs. In the Kafue Basin there are already conflicts on water rights due to water demand for various uses including agriculture, hydro-power generation, industry and domestic demand, which will intensify with climate change (Chigwada 2004, 28).

Drought threatens the energy security as it disrupts energy supplies from hydro-power systems. This will, in turn, have effects on the social and economic development of the society. The basic infrastructure for development, namely roads, bridges, transport, houses and services will be damaged by the effects of floods, cyclones, etc. Socio-economic impacts arising from climate change impacts on water and wetlands are likely to include shortages of potable water, food insecurity, poor health, extreme events and damage to infrastructure. Human health will be affected by the rise in temperature, which will extend the habitats of vectors of diseases such as malaria. Access to potable water and sanitation is very low during droughts while floods increase the frequency of epidemics and enteric diseases. Climate change will also have impacts on biodiversity (for example, altering the distribution range of antelope species). In mountain ecosystems, biodiversity is threatened by increases in temperature, because many ecosystems are isolated populations with no possibility of vertical or horizontal migration. Biodiversity forms an important source of livelihood with both consumptive uses, i.e. food, fibre, fuel, shelter, medicinal and wildlife trade, and non-consumptive uses, namely ecosystem services and the economically important tourism industry (Chigwada 2004, 32-33).

7.3. Vulnerability of development co-operation partners in Asia and Latin America

Nepal

The climate in Nepal varies from the tropical to the high Himalayan within a 200 km span from south to north. Much of Nepal falls within the monsoon region, with regional climate variations largely being a function of elevation. Mean temperature is about 15°C, temperature increases from north to south with the exception of mountain valleys. Average rainfall is 1500 mm, with rainfall increasing from west to east. The northwest corner has the least rainfall, being situated in the rain shadow of the Himalayas. Rainfall also varies by altitude; areas over 3000 m experience a lot of drizzle, while heavy downpours are common below 2000 m. Annual distribution of rainfall is uneven: flooding is frequent in the monsoon season during the summer, while droughts are not uncommon in certain regions in other parts of the year (Argawal et al. 2003).

Table 22 Nepal: key statistics and vulnerabilities[29]

Land area (km^2)	147 181
Population (2006)	27 678 000
Men/100 women	98
Annual population growth rate (2005 – 2006)	2.10
GDP per capita $ PPP valuation (2004)	1 490
Life expectancy (2004)	62.1
Illiteracy rate (2004)	51.4
Key vulnerabilities and impacts of climate change	▪ Glacier lake outburst flooding risk increases; magnitude of damages increases ▪ Rice yields are estimated to decline with rising temperatures

A warming trend has already been observed in Nepal. The temperature differences are most pronounced during the dry winter season, and least during the monsoon. There is also significantly greater warming at higher elevations in the northern part of the country than at lower elevations in the south. Significant glacier retreat as well as significant areal expansion of several glacial lakes has been documented in recent decades, with an extremely high likelihood that such impacts are linked to rising temperatures.

[29] Sources: Agrawal et al. 2003; United Nations 2007; IPCC 2007b; UNDP http://hdr.undp.org/hdr2006/statistics/countries/data_sheets/cty_ds_NPL.html

In Nepal, Himalayan glaciers in Shorang and Khumbu have been retreating on average 8-10m per year and since 1990 the retreat rate has been accelerating. The fastest retreating glacier has been the Imra glacier in Dudh Koshi with a rate of 74 m per year for the past half decade. Glacial lakes have grown at the same time as the glaciers have retreated and melted. The glacial lakes are moraine-dammed, and with large amounts of meltwater there is a risk of the dams being breached in outburst floods These can inflict considerable damage downstream (Bajracharya et al. 2007).

Figure 33 summarises projected changes in seasonal temperature and precipitation in Nepal during the 21st century from global climate models. A general increase in precipitation for the whole of Nepal is projected, with a gradient from south west to north east in the magnitude of 150 to 1050 mm at 2 x CO_2 level. The rainy season in Nepal including pre and post monsoon seasons will become more intense. Intensity would increase especially during June and July, while slightly lower than observed precipitation amounts are estimated for August. It is also estimated that winter and spring will be drier than today. Most of the Terai belt and western Nepal is expected to observe a mostly negative trend in precipitation (with a maximum decrease of <300 mm per decade in the Terai belt). Positive trends are expected in the hills and mountains of western and northeastern Nepal (up to 1100 mm per decade), and a negative trend of up to 700 mm per decade in the eastern and central part of the country (Nepal National Communication 2004).

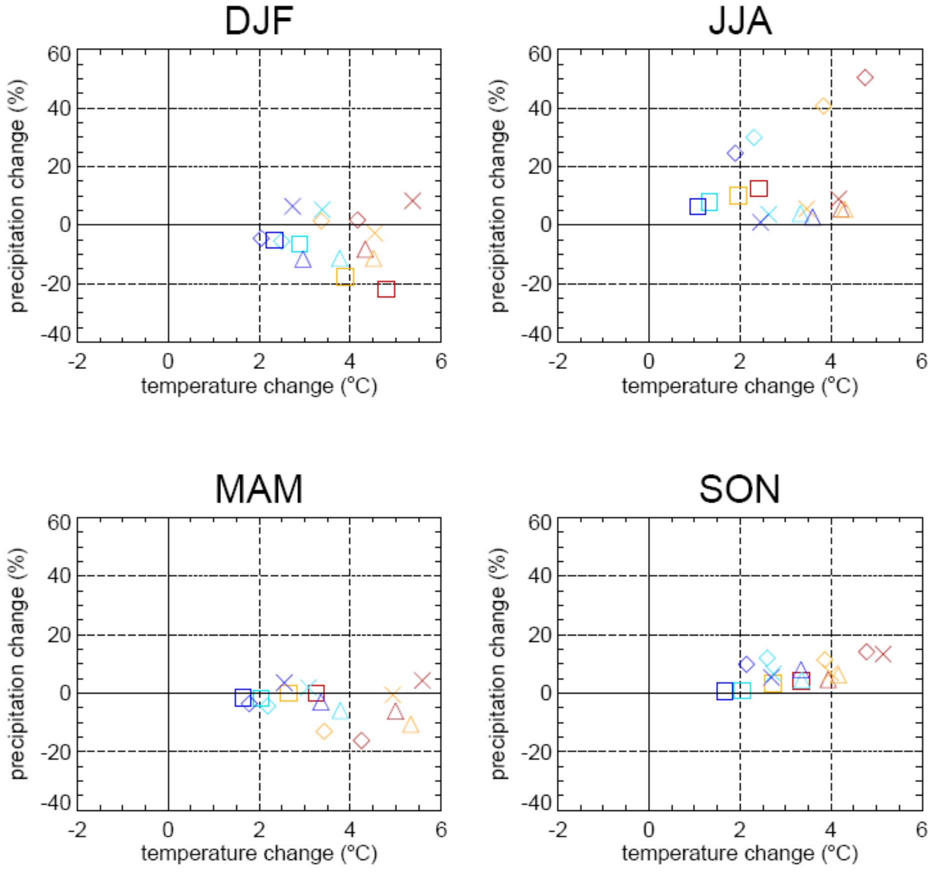

Figure 33 Nepal: projected changes in mean seasonal temperature (°C) and precipitation (percent) between the end of the 20th (1961-90) and the 21st (2070-99) centuries from four climate models (symbols): ◊ CGCM2 (Canada); Δ CSIROmk2 (Australia); □ DOE PCM (USA); x HadCM3 (UK), for four emissions scenarios (colours): A1FI – dark brown, A2 – light brown, B2 – light blue, B1 – dark blue. Seasons: DJF=December-February, MAM=March-May, JJA=June-August; SON=September-November. Sources: Mitchell et al. 2002; http://www.cru.uea.ac.uk/%7Etimm/climate/ateam/TYN_CY_3_0.html

The potential rice yields in Terai can be estimated to increase by about 18 - 21 % when CO_2 is doubled to 580 ppm. However, with an increase of temperature beyond 4º C, the yield is projected to decrease. An increase of temperature up to 4º C and rainfall to 20 % led to modelled yield increases of between about 1 - 7.5 %, and beyond that the yield level would continue to decline. In the hills, the condition is slightly different. The effect of temperature here is more severe than in the Terai. At 4º C rise, the yield potential declines by nearly 7 %. The situation in the mountain region is somewhat better than in the hills, but there is only a negligibly amount of rice grown there.

Glacial coverage is projected to be greatly diminished in the Himalayas. The extent and amount of snow will also decrease as temperatures increase and the snow line will rise to higher elevations. Water flow in the rivers (for example Indus), that receive most of their total water discharge from upper mountain catchments including glaciers and snow, could decline perhaps as much as 70% if the glaciers disappear. In some cases, the rivers could become seasonal. Reduced water flow in the dry season will lead to more and longer periods with critical shortages of water for transportation, drinking water and irrigation.

The impacts are not evenly distributed geographically or socially. High proportions of impoverished people in the region are mountain and foothill dwellers. In some mountain areas in Nepal, 94% of the energy supply comes from traditional fuel sources such as fuel wood and animal dung. Because of this dependence on fuel wood and livestock, most watersheds in the mountains have experienced deforestation and overgrazing, making the hillsides very vulnerable to landslides. High in the mountains, a rise in elevation of the snowline will lead to drying out of village grazing areas. Even slight increases in severity and frequency of land slides and flash floods may significantly reduce the ability of herders to move and transport their livestock between grazing areas and to town for sale (UNEP 2007, 131).

Glacier lake outburst floods represent the largest and most extensive glacial hazard, with the highest potential for disaster and damage, with up to 100 million m^3 break-out volume and up to 10 000 m^3 per second runoff. The Himalayans are among those regions most severely affected by this type of hazard. Glacier floods are of particular concern in view of the rapidly retreating glaciers and the corresponding formation and growth of numerous glacier lakes (UNEP 2007, 124).

Vietnam

Vietnam has a tropical monsoon type of climate with a single rainy season during the southern monsoon (May-Sep) and infrequent and light rainfall during the remainder of the year[30]. Annual rainfall exceeds 1000mm almost everywhere in the country and is highest in the hills, especially those facing the sea (2000-2500mm). Temperatures are high all year round for southern and central Vietnam, but northern Vietnam has a definite cooler season as the northern monsoon occasionally advects cold air in from China. Frost and some snow may occur on the highest mountains in the north for a few days a year. In southern Vietnam, the lowlands are sheltered from outbreaks of colder northerly air and the dry season is warm to hot with much sunshine. In northern Vietnam, the annual average temperature is 23ºC, and in January, the coldest month of the year, the mean temperature is 17ºC. In southern Vietnam, the average annual temperature ranges from 21ºC (Da Lat, in the highlands) to 27ºC (Ho Chi Minh City).

From north to south, the uplands of northern Vietnam can be divided into two distinct regions—the area north of the Red River and the massif that extends south of the Red River into neighbouring Laos. The country is mountainous in the northwest and in the central highlands facing the South China Sea, with peaks reaching up to 2450m. In the north around Hanoi and in the south around Ho

[30] http://www.vietnamembassy.org.uk/climate.html; http://www.britannica.com/eb/article-52693/Vietnam

Chi Minh City, there are extensive low-lying regions in the Red River delta and the Mekong delta, respectively.

Table 23 Vietnam: key statistics and vulnerabilities[31]

Land area (t km^2)	329 315
Population (2006)	85 344 000
Men/100 women	100
Annual population growth rate (2005 – 2006)	1.37
GDP per capita $ PPP valuation (2004)	2 745
Life expectancy (2004)	70.8
Illiteracy rate (2004)	9.7
Key vulnerabilities and impacts of climate change	▪ Coastal zone greatly affected: inundation, loss of mangrove forests, weakening of living conditions of people living in the coastal zone ▪ Sea and fresh water ecosystems affected with negative consequences for biodiversity, fishing ▪ Possibility of droughts increase ▪ Increased risk of flooding at the Mekong and Red River deltas due to changes in runoff

Figure 34 summarises projected changes in seasonal temperature and precipitation in Vietnam during the 21st century from global climate models. In response to simulated climate change, the length of period with air temperature lower than 20ºC would decrease 10-20 days by 2010, 20-30 days by 2050 and 30-50 days by 2070. In contrast, the length of period with air temperature ≥ 25ºC would increase 10-15 days by 2010, 15-45 days by 2050 and 30-80 days by 2070 (Vietnam Initial National Communication 2003).

Climate change, with increasing temperature, change of rainfall amount and sea level rise, is expected to have various effects on forest cover and forest ecology. The planting boundary of tropical trees/crops would move towards higher elevations and northwards. On the other hand, the adaptation area of subtropical plants would become narrower. By the 2070s, mountainous tropical trees would be able to grow 100-550 meters higher and move 100-200 km northwards in comparison with present.

Sea level rise would lead to a decline in mangrove forest. Warmer winters, on the other hand, would create favourable conditions for development of mangroves in the coastal zone of North Vietnam, but in the coastal zone of Central Vietnam the increasingly dry and hot weather would adversely affect the growth and development of mangroves. Coastal erosion and larger waves would also adversely affect mangrove forests. Indigo forests and forests planted on the sulphated land of provinces in the south of Vietnam would be adversely affected. Drought resistant deciduous forest could be expected to develop, due to reduced soil moisture and high plant evapotranspiration.. Risk of extinction of animal and plant species would increase; some important plants such as aloe wood, boswood, textured wood and siadora Vietnamese could be exhausted. The increase of temperature and drought would also lead to increasing danger of forest fires, and to the development and spread

[31] Sources: UNDP http://hdr.undp.org/hdr2006/statistics/countries/data_sheets/cty_ds_VNM.html; United Nations 2007, Initial National Communication of Vietnam 2003; https://www.cia.gov/library/publications/the-world-factbook/geos/vm.html; http://www.britannica.com/nations/Vietnam

of plant pests and diseases. Sea level rise by 1m would cause inundation, particularly in the Mekong Delta. Sea level rise would affect the wet land area in the coastal zone of Vietnam, most seriously in the forest area of Ca Mau province, Ho Chi Minh City, Vung Tau and Xuan Thuy sea areas (in Nam Dinh Province). Sea level rise might submerge a large number of existing forests (Vietnam Initial National Communication 2003, 69).

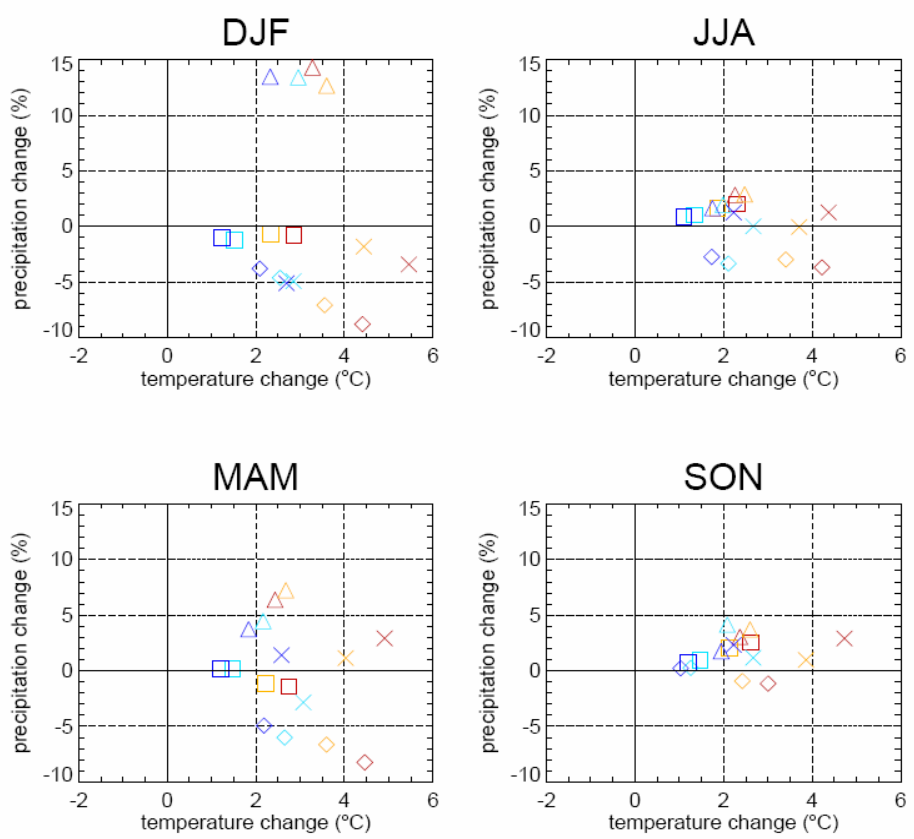

Figure 34 Vietnam: projected changes in mean seasonal temperature (°C) and precipitation (percent) between the end of the 20th (1961-90) and the 21st (2070-99) centuries from four climate models (symbols): ◊ CGCM2 (Canada); Δ CSIROmk2 (Australia); □ DOE PCM (USA); x HadCM3 (UK), for four emissions scenarios (colours): A1FI – dark brown, A2 – light brown, B2 – light blue, B1 – dark blue. Seasons: DJF=December-February, MAM=March-May, JJA=June-August; SON=September-November. Sources: Mitchell et al. 2002; http://www.cru.uea.ac.uk/%7Etimm/climate/ateam/TYN_CY_3_0.html

Vietnam is located downstream of two large rivers: the Mekong and Red Rivers. The total runoff from both rivers reaches 835 billion m^3. The spatial and temporal distribution of runoff is very uneven. More than 80% of runoff concentrates in summer (5-6 months), the rest during the dry season (6-7 months). In some areas, such as the mountainous areas of Thua Thien and Bac Quang provinces, runoff is high, but in other areas runoff is small, such as in the rivers of Binh Thuan province. By 2070, for medium and small rivers, the biggest decreases of annual runoff are projected in the east of South Vietnam (29-33%), Central Vietnam from Quang Binh to Quang Ngai province (23-40.5%), North Vietnam and north of Central Vietnam (2-11.5%). The largest increase in extreme runoff is projected in the south of Central Vietnam (49%), and the Central Highlands (6-16%) (Vietnam Initial National Communication 2003).

Due to changes of rainfall intensity, flood inundation and drought would occur more frequently. Significant cultivation areas in the Mekong and Red River deltas would be inundated by salt water due to sea level rise. The Red River Delta in Northern Vietnam is a low-lying area with a dense population and intensive agriculture. The months from August to November are the flooding period in the Mekong Delta, when a further increment in water levels is especially critical. No other crop than rice can be grown under these adverse conditions of unstable flooding and – in many locations – moderate salinity in the dry season. Most farmers in flood-prone rice areas are very poor, with limited options to divert to other sources of income. Sea level rise will lead to increased tidal flow and possibly also to changes in the distribution of discharge over the various Delta branches, thus influencing the mean water levels. Climate change and deforestation in the catchment areas will change the river discharge and sediment regime and probably change the flood risk. In the Vietnamese part of the Mekong Delta, rice production constitutes almost 80% of the land use. Although 60% of the soils are acid sulphate and saline soils, rice production has markedly increased in recent years allowing Vietnam to become the third largest rice exporter in the world (Sanh et al., 1998). The bulk of the land in the Mekong delta is only slightly (<2 m) above mean sea level. The Mekong Delta has experienced devastating river floods e.g., in September/October 2000, leading to huge economic losses in the agricultural sector. These losses could be substantially exacerbated under sea level rise (Wassmann et al. 2004; Vreugdenhil et al. 2000; Vietnam Initial National Communication 2003).

Due to sea level rise, saline intrusion would reduce habitats of fresh water species. Seaweed production could be altered and have consequences for fish and other aquatic species both in sea- and in river-beds. An increase of water temperatures would lead to clearer thermal vertical stratification which would affect the habitats of fresh water species. With increasing temperature, some species would migrate northwards or to deeper depths and the vertical distribution structure of aquatic species would change. Warming would also affect productivity and commercial quality of aquacultural and sea products and it is estimated that economic production capacity of the sea would be reduced at least one third relative to the present. A number of sub-tropical fish with high commercial value would decline or even disappear. Meanwhile, the number of tropical fish species with low commercial value, except tuna, would increase. Most fish in coral reef ecosystems would vanish. Due to large rainfall intensity, salt concentration of seawater could reduce by 10 - 20% during periods of some days to some weeks. As a result, brackish water and coastal species, especially, dual crust molluscs (like arca, oyster, etc.) would experience mass mortality because they cannot tolerate changes in salt concentration (Vietnam Initial National Communication 2003, 70-71).

In the Mekong and Red River deltas and the Central coastal zone, sea level rise would reduce land area, unless coastal dyke systems are constructed. Storm surges are also projected to become stronger, threatening structures in the coastal zone and low lands. Increased inundation would negatively affect the foundations of structures, and a projected increase of tropical typhoons would require strengthening the resistance of structures, hence escalating construction costs (Vietnam Initial National Communication 2003, 71).

Warmer climate would have adverse impacts on human health. Extreme weather would threaten especially elderly people; people suffering from cardiac disease and mental disorders. Warming climate would also change seasonal structure and could affect biological rhythms in the human population. An increase of natural disasters such as typhoons, storm surges, strong winds, and heavy rain would threaten the life of people in many regions, particularly in coastal and mountainous areas (Vietnam Initial National Communication 2003, 74).

Nicaragua

Temperature varies little with the seasons in Nicaragua and is largely a function of elevation[32]. The tierra caliente, or the "hot land," is characteristic of the foothills and lowlands to about 750 metres of elevation. The daytime temperatures average 30°C to 33°C in the region, and night temperatures 21°C - 24°C for most of the year. The tierra templada, or the "temperate land," is characteristic of most of the central highlands, where elevations range between 750 and 1600 metres. Daytime temperatures are mild (24 - 27°C), and nights are cool (15 - 21°C). Tierra fría, the "cold land," at elevations above 1600 meters, is found only on and near the highest peaks of the central highlands. Daytime averages in this region are 22° - 24°C, with nighttime lows below 15°C.

Table 24 Nicaragua: key statistics and vulnerabilities[33]

Land area (km^2)	129 494
Population (2006)	5 600 000
Men/100 women	100
Annual population growth rate (2005 – 2006)	2.02
GDP per capita $ PPP valuation (2004)	3 634
Life expectancy (2006)	70.9
Illiteracy rate (2004)	23.3
Key vulnerabilities and impacts of climate change	▪ Increased risk of flooding ▪ Increased risk of bush fires ▪ Increase in intensity of tropical cyclones

The Pacific side of the country is characterized by a rainy season from May to November and a dry season from December to April. The annual average temperature is 27 °C, and precipitation averages 1910 mm yearly. On the Caribbean side of the country, the rainy season lasts for about nine months of the year, and a dry season extends from March through May. The annual average temperature is 26 °C, and annual precipitation averages almost 3810 mm. In the northern mountains temperatures are cooler and average about 18 °C. Prevailing winds are from the northeast and are cool on the high plateau, warm and humid in the lowland.

During the rainy season, eastern Nicaragua is subject to heavy flooding along the upper and middle reaches of all major rivers. Near the coast, where river courses widen and river banks and natural levees are low, floodwaters spill over onto the floodplains until large sections of the lowlands become continuous sheets of water. River bank agricultural plots are often heavily damaged, and considerable numbers of savanna animals die during these floods. The coast is also subject to destructive tropical storms and hurricanes, particularly from July through October. The high winds and floods accompanying these storms often cause considerable destruction of property. In addition, heavy rains accompanying the passage of a cold front or a low-pressure area may sweep from the north through both eastern and western Nicaragua from November through March. Hurricanes or heavy rains in the central highlands, where agriculture has destroyed much of the natural vegetation, also cause considerable crop damage and soil erosion. In 1988, Hurricane Joan forced hundreds of

[32] http://countrystudies.us/nicaragua/21.htm; http://www.britannica.com/eb/article-40972/Nicaragua
[33] United Nations 2007; CIA World Factbook 2007 https://www.cia.gov/library/publications/the-world-factbook/geos/nu.html#People; UNISEF http://www.unicef.org/infobycountry/nicaragua_statistics.html; Human Development Report UNEP 2006 http://hdr.undp.org/hdr2006/statistics/countries/country_fact_sheets/cty_fs_NIC.html

thousands of Nicaraguans to flee their homes and caused more than US$1 billion in damage, most of it along the Caribbean coast.

Figure 35 summarises projected changes in seasonal temperature and precipitation in Nicaragua during the 21st century from global climate models. Annual mean precipitation is expected to decrease by 8% by 2010 to 37% by 2100, relative to 1961-1990. Mean annual temperature is projected to rise by 0.8ºC up to 2010 and by 1 - 5ºC by 2100 for different scenarios. The most significant changes in precipitation are expected in areas that are already dry, such as the northern part of the country, and the area north of Chinandega and León. The annual precipitation in these areas is expected to fall below 500 mm, which would have important adverse effects on agriculture and animal husbandry (Primera Comunicacion, 2001). The frequency and occurrence of extreme weather events such as windstorms, tornados, hail, heat waves and heavy precipitation are expected to increase in the future with climate change. In Central America, projected mean precipitation decrease is accompanied by more frequent dry extremes in all seasons (IPCC 2007b, 13/20).

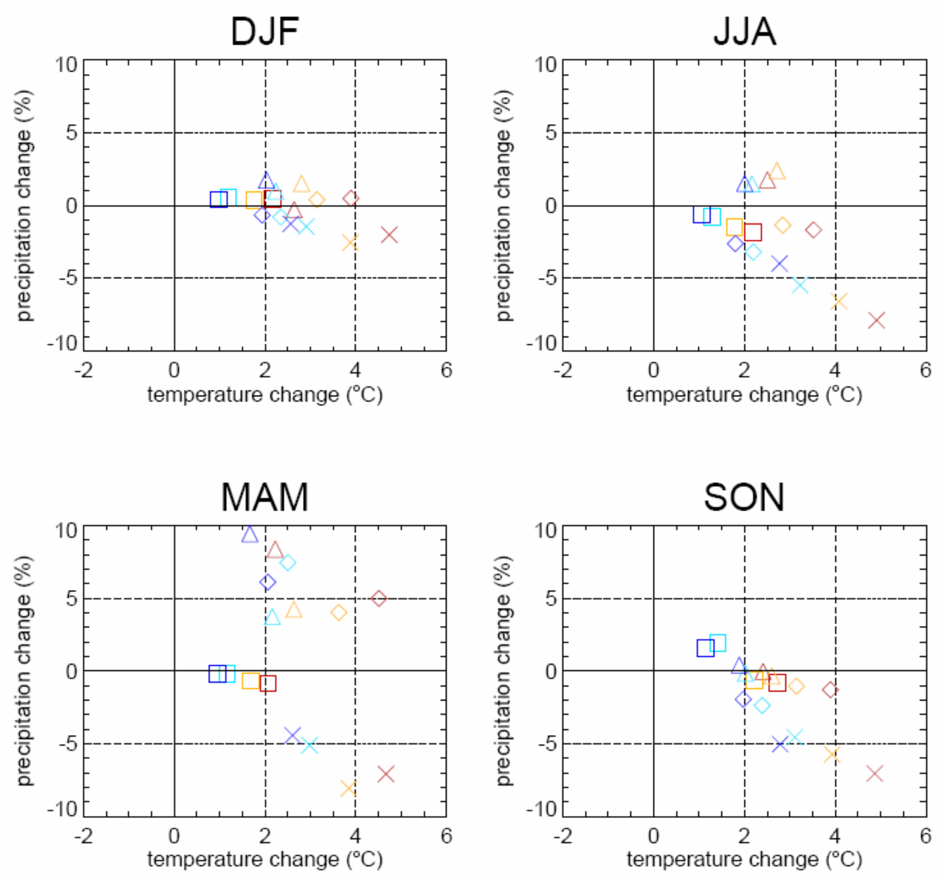

Figure 35 Nicaragua: projected changes in mean seasonal temperature (°C) and precipitation (percent) between the end of the 20th (1961-90) and the 21st (2070-99) centuries from four climate models (symbols): ◊ CGCM2 (Canada); Δ CSIROmk2 (Australia); □ DOE PCM (USA); x HadCM3 (UK), for four emissions scenarios (colours): A1FI – dark brown, A2 – light brown, B2 – light blue, B1 – dark blue. Seasons: DJF=December-February, MAM=March-May, JJA=June-August; SON=September-November. Sources: Mitchell et al. 2002; http://www.cru.uea.ac.uk/%7Etimm/climate/ateam/TYN_CY_3_0.html

Changes in runoff will affect hydropower production and create situations where different users compete for scarce resources. The watersheds of the rivers El Tamarindo, Río Viejo and Guanas are very vulnerable to climate change. Groundwater resources will also be affected, with decreases expected by 2050. The cities of Nicaragua are also vulnerable to the impacts of climate change due to water stress and water quality problems (Primera Comunicacion 2001).

7.4. General issues of development in relation to climate change

Climate change will affect the potential for development in many developing countries by reducing the production potential of the economy. The magnitude of this impact depends on vulnerability and the country's institutional capacity to adapt. Weak institutions in developing countries may hamper the capacity to adapt or to mitigate climate change. Institutions can be understood as the core allocation mechanisms and the structure of society that organises markets and other interactions. Their role is critical in an economy's capacity to use resources optimally. Therefore policies should enhance institutions such as the financial sector, information and risk sharing, as well as general market development. Most economic sectors that are a focus for development efforts are climate sensitive, including agriculture, water resources, forestry, health, energy and infrastructure. Climate change adaptation as well as mitigation can include policies like financial and technology transfer, institutional strengthening and market improvements that enhance the productive capacity of the country. Incorporating climate knowledge into the work could also enhance the effectiveness of development efforts (Hellmuth et al. 2007; Halsnaes and Verhagen 2007, 667- 678).

Many developing countries deviate from optimal resource allocation. However, climate policy measures often aim for optimal resource allocation by internalising environmental externalities like climate change into the market mechanism. Instruments such as taxes, emission trading and insurance markets are used. Therefore, these policy recommendations need to be considered cautiously when implemented in a context, where current market structures and resource allocation are far from optimal (Halsnaes and Verhagen 2007, 667-668).

According to UNDP (2002), strengthening national and local capacities to manage climate-related risks and addressing short-term vulnerabilities is the best strategy to be able to manage more complex climate risks in the future. Medium and long-term adaptation should begin today with efforts to improve current risk management and adaptation. It is also more feasible to mobilize national and international resources to manage an existing risk than to address a hypothetical future scenario. Adaptation and disaster risk reduction efforts need to be integrated into climate risk management (World Bank 2006, 23; Halsnaes and Verhagen 2007, 678).

There exist synergies between climate change policies and the sustainable development agenda in developing countries. These include energy efficiency, renewable energy, transport and sustainable land-use policies. For example, promotion of renewable energy is a mitigation measure with positive climate effects, but it also helps to attain poverty alleviation, clean development and sustainable development goals. Adaptation strategies can also improve the efficiency of economies by strengthening local institutions and introducing new technologies. There could be synergies between climate change and other policies such as those designed to combat desertification and preserve biodiversity. There are also many linkages between the Millennium Development Goals and climate change policies – for example, between the goal of poverty alleviation and climate policy objectives such as improved energy access and increased food and water supply (Hellmuth et al. 2007, 3; Beg et al. 2002; Halsnaes and Verhagen 2007, 672, 678; UNDP/GEF 2004).

Climate change will also affect insurance options in the developing world. This arises from a combination of inferior disaster preparedness and recovery, more vulnerable infrastructure due to lack or non-enforcement of building codes, high dependency on coastal and agricultural economic activities, and lack of funds to invest in disaster-resilient adaptation projects. As insurability declines because of larger risks associated with climate change, private insurers face increasing difficulties in handling the risks. As commercial insurability declines, demands emerge to expand existing government-provided insurance for flood and crop, and to assume new risks such as wildfires and storms. Ultimate costs will most likely be shifted back to individuals and businesses affected by climate change. In developing countries lack of insurance is compounded because in general international aid for natural disasters has declined as a percentage of donor country GDP in recent years (Mills 2005, 1042).

Climate science and climate considerations need to be integrated into multidisciplinary development planning and projects. The approach should be participatory, involving all primary stakeholders to ensure that the real needs are met (Hellmuth et al. 2007, 3). Climate sensitive projects are those that are at risk themselves, such as an investment that could be destroyed by flooding. But projects that affect the vulnerability of other natural or human systems can also be regarded as climate sensitive. For instance, new roads might be fully weatherproof from an engineering standpoint, but they may also trigger new settlements in high-risk areas, or they may have a negative effect on the resilience of the natural environment, thus exposing the area to increased climate risks. These considerations should be taken into account in development project design and implementation (Argawal et al. 2003, 22).

Within climate sensitive sectors there can be a wide spectrum of exposure to climate risks. For example, rain-fed agriculture projects may be much more vulnerable than projects in areas with reliable irrigation. At the same time, the irrigation systems themselves may also be at risk, further complicating the picture. Similarly, most education projects would hardly be affected by climatic circumstances, but school buildings in flood-prone areas may well be at risk. Without an in-depth examination of risks to individual projects, it is impossible to capture such differences (Argawal et al. 2003, 22).

It should also be remembered that climate is only one factor affecting development. For example, strengthening livelihoods and off-farm activities would reduce poor farmers’ vulnerability to climate variability and extremes. Incorporating climate information into development work also has the potential for synergistic results. In the face of an uncertain climate, farmers play safe and adopt conservative management strategies, which could be less profitable in the longer run. Reducing climate uncertainty could help farmers to invest in new technologies and more innovative approaches.

8. Conclusions: potential impacts and policy considerations

8.1. International impacts of climate change and their potential effects on Finland

Research on the impacts of climate change in Finland indicates that in the near future, and if climate change is not very rapid or strong, there could be mixed impacts for Finland, some beneficial such as increased growth of forests and some negative such as increased risk of floods and periods of droughts. In these circumstances, the largest implications of climate change for Finland could come from impacts outside Finland, which in many regions are expected to be severe even under moderate amounts of global warming. Climate change can have impacts on the world economy and development and have repercussions for the Finnish economy and society. Moreover, international climate policy to address the global problems described in this report will have direct implications for Finnish policy making and society.

On the other hand, if regional climate change is rapid, or if there are abrupt changes brought about by the climate system crossing some critical threshold, then impacts in Finland could be more negative and severe. For example, high rates of warming and a northward shifts in vegetation zones may exceed the natural capacity of forest ecosystems to adapt. This, combined with rapid invasions of exotic pests and diseases, stronger wind storms, heavy precipitation events and prolonged periods of drought, could lead to acute problems of forest disturbance through fire, pest attack and wind throw. Events such as a rapid melting of the Greenland and west Antarctic ice sheets could increase sea level substantially, which would affect Finland both directly but also indirectly though the damaging impacts of sea level rise felt worldwide. An abrupt transition of the North Atlantic Current, though regarded as very unlikely during the 21st century (IPCC 2007a), would cause cooling across much of Fennoscandia, with severe impacts in many sectors.

Under either of the above scenarios, climate change impacts in other parts of the world are likely to have implications for Finnish society. In Finland itself, and with the exception of abrupt discontinuities in the climate system, climate change is unlikely to be the major factor or driving force of change during the coming century. Other factors, of a political, economic, and institutional nature, will determine the rate and direction of change and the outcome. Agriculture, forestry, energy, transport and tourism are among the sectors that are likely to be affected by climate change impacts in Finland and elsewhere in the world. However, the manner in which these effects are manifested is likely to be strongly influenced by policy.

Agricultural production worldwide will be affected by climate change. Production conditions are expected to deteriorate in some parts of the world, including parts of Africa, Latin America and the Mediterranean region. Changes in agricultural production could affect prices, and Finland's competitive position with the rest of the world could change. However, the eventual outcomes will be dependent on other factors than climate alone. Agricultural policies dominate the agricultural sector in Europe, and issues such as the allocation of land to meet demand for bioenergy as well as food could have large impacts on Finnish agriculture. It is possible, however, that improved production potential under a changing climate may raise Finland's competitive position and the demand for agricultural land area may increase in the future, with possible intensification of agriculture in southern Finland (Hilden et al. 2005).

The OECD estimates that international market prices for agricultural commodities will increase due to increased demand for biofuel production (OECD 2007). Prices of feedstock, in particular , are expected to increase, as there will be more competition for its use as animal feed or as biofuel.

Higher commodity prices will affect most of the net food importing developing countries and poor urban populations everywhere. Costs are likely to increase for livestock farmers , affecting the profitability of production. In Finland too, crop prices and, indirectly through higher feed costs, the prices for livestock products are expected to increase. In the next 10 years, substantial amounts of maize in the US, wheat and rapeseed in the EU and sugar in Brazil will be used for ethanol and bio-diesel production (OECD 2007). In most temperate zone countries ethanol and bio-diesel production are currently not economically viable without support. However, new production technologies, changes in biofuel policies and/or in crude oil prices could affect the production costs and prices of biofuels.

Climate change impacts in other parts of the world can affect the Finnish forest sector in several ways. Demand for Finnish wood is expected to change due to increased global demand for wood bioenergy. An increase in demand for wood for energy production could change the price of wood, but also its availability as a raw material for forest industries. In Finland, forest growth is expected to increase due to climate change, but other regions in the world could be negatively affected. In some parts of Latin America there is a high risk of forest loss and conditions for forests are projected to deteriorate in some regions. If forest plantations in a region are also negatively affected, this could have consequences for the supply of wood as a raw material and for forest industries in the region. The importance of forests as carbon sinks can increase in the future, possibly changing the primary management goals of some forests from wood production to carbon sequestration and recreational use. Nature based tourism is projected to increase in the future as well, and if conditions at destinations that are currently popular for tourism deteriorate due to climate change, the attractiveness of Finland as an alternative destination for foreign tourists could increase, and the recreational importance of Finnish forests and nature reserves will be enhanced.

Climate change is expected to affect the skiing areas in the Alps – the number of naturally snow-reliable areas is projected to drop to about two-thirds of the current areas under a warming of 2ºC. It is possible that the number of ski tourists to central and northern Finland – where reliable seasonal snow cover is anticipated for at least the next few decades – will increase in the future. However, it is also possible that there will be behavioural changes, with people switching to other types of sports and recreation. The Mediterranean region is currently the most popular tourist destination in the world. Climate change is projected to change the summer conditions there and increase heat waves and droughts in the region. The Mediterranean could therefore lose its attractiveness as a summer tourism destination. Tourism could shift northwards in the summer, and Baltic Sea locations, including Finland, have been touted as attractive alternatives as summer tourist destinations. Finns themselves may also change their behaviour and travel more in Finland during the summer. The outcome of these impacts on the tourism industry in Finland will be determined by the tourists' responses to the changes. It is likely, though, that at least in the near future there could be some benefits to summer tourism in Finland and to snow-based tourism in northern Finland.

Reliable energy supply is crucial for Finland. Climate change could affect energy supply and transmission in Scandinavia and Russia. Storms, increased windiness and changed ice and snow conditions could affect the electricity transmission lines and cause power outages. Thawing permafrost can damage oil and gas pipes and cause breaks in supply. On the other hand, hydro-electric power potential is estimated to increase with a warmer and wetter climate in Fennoscandia.

Climate warming is already affecting the Arctic sea ice cover. In the future, if the trend of sea ice melting continues, the northern sea routes could become navigable for seasonal transport, and natural resource exploitation in the Arctic Sea region could increase. Together, these developments could have important geopolitical implications, including consequences for Finland and for the regional development in the Arctic. For example, a larger proportion of transport to and from Russia could go through northern Finland. The importance of the Baltic Sea for marine transport could change with enhanced seasonal access through the Gulf of Bothnia. Enhanced exploitation of natural resources in the Arctic Ocean could also have implications for regional development and planning in northern Finland.

The impacts of climate change on the Finnish economy are not expected to be very large in the near future. Economic aggregate impacts are probably modest, but climate change induced changes in foreign trade could be an important source of economic impacts for Finland. However, so far the magnitude of these impacts has not been assessed. The Ministry of Finance has estimated that mitigation measures would bring challenges to the Finnish economy and could lead to reduced production and employment level in Finland (Ministry of Finance 2007). Gradual mitigation measures would have smaller impacts than abrupt changes in policies. However, climate policies could also bring benefits, through damages avoided with mitigation and adaptation policies and through ancillary benefits. If climate policies reduce the dependency on fossil fuels, other benefits than climate protection include possible reductions in air pollution, benefits to energy security and less marine pollution from oil spills (Perrels et al. 2005; Ministry of Finance 2007).

Climate change has many potential environmental consequences and will have profound implications for the quality of life and livelihoods of hundreds of millions of people. The impacts of climate change on water resources and agricultural production in the world could be one factor in emergence of conflicts and forced migration. The causal chains and links between climate change and conflicts are complex, though, and it is difficult to show how much climate related impacts affect the emergence of conflicts and migration. For example, part of the likely climate-related reduction in agricultural and resource-based employment can be absorbed by processes of economic change. Also, large migration is already on-going in the world. The urban population is growing worldwide and it could be difficult to distinguish this population movement from environmental forced migration. Urban populations, and particularly the urban poor, are already vulnerable to climate change. There are large mega cities in developing countries in low elevation coastal zones that are vulnerable to sea level rise. Increased migration to these cities could exacerbate the problems and the migrants themselves are likely to be highly vulnerable (Nordås and Gleditsch 2007, UNFPA 2007). However, forced migration is an issue that needs to be taken into consideration in development co-operation, international policies and possibly also in national refugee policies. Currently there is no category in the UNFCR classification of refugees for environmental refugees, but it is possible that this group of refugees will increase in the future and their needs and rights will need to be taken into consideration.

8.2. Policy implications of international climate change impacts

Climate change impacts elsewhere in the world and international climate policy will have implications for Finnish policymaking. International commitments and EU regulations need to be taken into account in national strategies, laws and regulations. There is also a need to mainstream change issues into development co-operation strategies, plans and measures in Finland, which has already been recognised in Finnish development co-operation.

Finland ratified the UNFCCC in 1994 and the Kyoto Protocol in 2002, together with the other EU countries. In the international climate negotiations, Finland acts as part of the EU. The European Union underlines the importance of achieving the objective of limiting the global average temperature increase to not more than 2ºC above pre-industrial levels. An integrated approach to climate and energy policy is needed to realise this objective. The EU endorses, inter alia, the strengthening and extension of global carbon markets, the development, deployment and transfer of necessary technology to reduce emissions, appropriate adaptation measures, action on deforestation and addressing emissions from aviation and maritime transportation, as essential parts of an effective and appropriate framework beyond 2012 (The Council of the European Union 2007). Finland will have to take these objectives and measures into account when making national policies and strategies. Also, questions of justice and compensation for those suffering most of climate change should be considered in international climate policymaking. It is necessary to involve all countries in climate negotiations and decision making – especially those that are most severely affected.

The Arctic Council in its Inari Declaration (2002) recognises that global climate change will have large consequences in the Arctic and that the Arctic can act as an early warning of global climate changes. The Arctic Council emphasized the importance of continued dialogue on consequences and policy measures among national governments, local communities, regional administrations, business community and researches and early capacity building for mitigation and adaptation.

Many international and multinational agencies are stressing the need to mainstream climate change issues into development co-operation strategies and plans and sectoral strategies. Some central issues include disaster management and risk management, improving security, technology transfer, capacity building for adaptation, education and awareness building, creating insurance options, and including stakeholders. Development co-operation efforts should be targeted to ensure protection of individuals from climate related disasters and the prevention of loss of housing and means of livelihood due to climate induced hazards, so that the numbers of people forced to migrate due to environmental changes can be reduced. Also, in international policy making, the rights and opinions of potential forced migrants should be heard.

The objective of the Nairobi Work Programme is to assist parties to the UNFCCC, in particular developing countries, to improve their understanding and assessment of impacts. vulnerability and adaptation, and to assist the countries to make informed decisions on practical adaptation actions and measures to respond to climate change on a sound scientific, technical and socio-economic basis. Responses to climate change should be coordinated with social and economic development in an integrated manner and with a view of avoiding adverse impacts to economic development. Experiences and lessons should also be taken from adaptation activities already undertaken in different countries and at national, sectoral and local levels.

The Finnish development co-operation partners are vulnerable to many impacts of climate change. In Africa, the partner countries face increased risks of water stress, droughts and floods and adverse impacts to agricultural production. In Asia, risks to the partner countries include declining yields, biodiversity loss and risks of flooding. Climate change could increase food insecurity in some regions in the world, Africa and parts of Asia would be most at risk. In central America, risks of climate change include increased floods and intensity of tropical cyclones. Under the UNFCCC, facilitating comprehensive national adaptation strategies and committing reliable funding for high-priority implementation projects are supported for proactive adaptation. Also mandatory climate risk assessments similar to environmental assessments should be part of development co-operation projects. Climate insurance measures would commit funds to support climate relief or insurance-type approaches in vulnerable countries for losses resulting from both climate change and current climate variability (Burton et al. 2006).

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Annex 1: Projected impacts of climate change in different world regions

Table A 1 Projected climate change impacts in Europe[34]

Sector	Impacts	Hot spots/ vulnerabilities
Water resources, aquatic ecosystems	▪ Higher risks of oxygen depletion, eutrophication, algal blooms and increased growth of toxic syanobacteria in lakes and rivers and brackish water due to longer growing seasons, warming of inland waters. In southern Europe, salinisation of inland waters can increase due to lower volume. ▪ Increased frequency of high rainfall events could increase nutrient discharge	▪ Increased water stress in C and S Europe by the end of the century
Agriculture	▪ In northern Europe, increases in crop yields are expected. Yield is expected to increase for autumn-sown crops. Some southern crops (maize, soybean, sunflower) will become more suitable further north or higher altitudes ▪ Largest reductions in crop yields are expected in the Mediterranean, southwest Balkans and in the south of European Russia. For spring- and autumn sown crops decreases in yield are expected in S Europe as well as increased water demand for spring sown crops ▪ In the Mediterranean, extreme climate events are likely to reduce the yield of summer crops (heat stress, higher rainfall intensity, longer dry spells)	▪ In the Mediterranean increased risk of droughts, water stress, crop yield reduction
Forests	▪ In N Europe, net primary productivity and biomass of forests are expected to increase substantially. Forest area is expands in the north, and current tundra area decreases. In N Europe, snow cover will decrease, frost free periods and winter rainfall increase => increased soil water logging and winter floods. Frost damage is expected to be reduced in winter, remain unchanged in spring and become more severe in autumn due to late hardening ▪ Native conifers are likely to be replaced by deciduous trees in W and Central Europe. By 2071-2100 in continental Central Europe and S Europe NPP of conifers is likely to decrease due to water limitations and higher temperatures. ▪ Fire danger, length of fire season and fire frequency and severity likely to increase in the Mediterranean ▪ The range of important forest insect pests may expand northward	▪ Increased risk of wild fire ▪ Increased risk of droughts ▪ Water stress increases in S and Central Europe
Biodiversity	▪ Range of plants is likely to expand northward and contract in southern mountains and the Mediterranean basin. Species would generally shift form SW to NE. ▪ Sea level rise will have major impacts for biodiversity: flooding of the haul-out sites of seals, increased risk of diseases for dolphins, loss of habitat of seals relying on ice for breeding, deterioration of wetlands ▪ A 1ºC warming in the Alps could result in the loss of 40% of local endemic plants, a 5ºC warming would produce a 97% loss ▪ Under a 2-3ºC warming, loss >50% of coastal wetland habitat likely	▪ More than half of modelled European flora species (10% of all) could become vulnerable, endangered, critically endangered or committed to extinction by 2080 if they were unable to disperse.

[34] Sources: Alcamo et al. 2007; EEA 2005; Stern 2006

Energy	▪ Demand for heating decreases and demand for cooling increases ▪ By 2070s, hydropower potential for the whole of Europe is expected to decline by 6%: to decrease 20-50% around Mediterranean and increase 15-30% in N and E Europe ▪ Land area devoted to biofuels may increase by a factor of two to three in all parts of Europe. ▪ More solar energy will be available in the Mediterranean region	▪ Hydropower potential decreases ▪ Area of biofuels estimated to increase ▪ Distribution of energy is vulnerable to climate change
Settlements and,transport	▪ High winds may affect safety of air, sea and land transport ▪ Reduced incidences of frost and snow will reduce maintenance and treatment cost. Reduced ground frost will decrease carrying capacity of some roads. Thawing of ground permafrost will disrupt access through shorter ice road seasons and can cause damage to infrastructure ▪ Droughts and reduced runoff may affect river navigation on major thoroughfares such as the Rhine, shrinkage and subsidence may damage infrastructure ▪ Reduced sea ice and thawing around the Arctic will increase marine access and navigable periods for the Northern Sea Route	▪ Increased risk of erosion and landslides
Health	▪ Increased risk of heat waves	
Tourism	▪ Higher summer temperatures may lead to a gradual decrease in summer tourism in the Mediterranean, but an increase in tourism in spring and autumn ▪ Ski industry in central Europe is likely to be disrupted by significant reductions in natural snow cover – a 1ºC rise leads to 4 fewer weeks of skiing days in winter and 6 fewer weeks in spring in the Austrian Alps (600 m in winter and 1400 m in spring)	▪ Summer tourism in the Mediterranean at risk ▪ Winter tourism at the Alps at risk
Mountain ecosystems	▪ Duration of snow cover expected to decrease by several weeks for each ºC of temperature increase in the Alps region and in middle elevations ▪ An upward shift of the glacier equilibrium line 60-140 m/ºC. Glaciers will experience a substantial retreat during this century; small glaciers will disappear, larger glaciers will suffer a volume reduction of 30-70% by 2050. Spring and summer discharge of water to rivers fed by meltwater will decrease. ▪ Lower elevation of permafrost is likely to rise by several 100 meters ▪ Mountain walls will be destabilised, frequency of rock falls increase ▪ Treeline in predicted to move upward by several hundred meters	▪ Glacier retreat and decrease in spring and summer discharge ▪ Risk of avalanches and erosion increases ▪ Large changes in mountain flora and fauna ▪ Permafrost is thawing/disappearing
Coastal areas and lowlands	▪ Some further increase in wind speeds and storm intensity in the north-eastern Atlantic (2010-2030), with a shift of storm centre maxima closer to European coasts => wind-driven waves and storm surges => erosion and flooding in estuaries, deltas and embayments ▪ Sea level rise: flooding, land loss, salinisation of groundwater, destruction of built property and infrastructure	▪ Coastal flooding could affect large populations ▪ Risks associated with increased storms

Table A 2 Projected climate change impacts in North America[35]

Sector	Impacts	Hot spots/ vulnerabilities
Water resources, aquatic ecosystems	▪ Earlier melting and significant reductions in snowpack in the western mountains by mid century are expected. In mountain snowmelt-dominated watersheds, snowmelt run-off advances and winter and early spring flows increase, summer flows decrease substantially ▪ Heavily-utilised ground water systems in the southwest U.S. are likely to experience additional stress that leads to decreased recharge ▪ Warming of lakes is likely to extend and intensify summer thermal stratification, contributing to oxygen depletion	▪ Heavily utilised water systems in western U.S. and Canada will be especially vulnerable ▪ Increased risk of heavy precipitation events but also droughts
Agriculture	▪ With moderate climate change, yields will likely increase in rain fed agriculture (5-20%, first half of the century), but spatial variability is large ▪ For corn, rice, sorghum, soybean, wheat, common forages, cotton positive effects are expected ▪ Crops that are currently near climate thresholds (wine in California) will suffer decreases in yields and quality even with modest warming ▪ Risks for early season frost and damaging winter thaws for fruit production in Great Lakes and Canada ▪ Possibility for late season heat stress for soybean ▪ There is potential for increased drought in the U.S. Great Plains/Canadian Prairies and opportunities for a limited northward shift of production areas in Canada.	▪ Decreasing precipitation a challenge
Forests	▪ Overall forest growth will increase 10-20% over this century. Mixed to positive effects for commercial forestry ▪ Greater water limitations in western forests expected ▪ Increased NPP at higher latitudes, result of expansion of forests into tundra and longer growing seasons ▪ Climate change is likely to cause changes in the nature and extent fire and insect outbreaks. Possibility of changes in fire regimes, including an earlier start to the fire season, and significant increases in the area experiencing high to extreme fire danger.	▪ Disturbances from pests and wild fires
Biodiversity	▪ Warming will lengthen growing seasons ▪ Drought limited ecosystems projected to increase 11% per degree of warming in the continental U.S.	
Energy	▪ A significant increase in demand for electricity for space cooling expected	
Settlements and transport	▪ Infrastructure in Alaska and northern Canada vulnerable to warming, thawing of permafrost creates problems ▪ Urban flood risks increase ▪ Warmer and less snowy winters will likely reduce delays, improve ground and air transportation reliability, decrease the need for winter road maintenance ▪ More intense storms could increase risks for traveller safety and require increased snow removal ▪ Coastal and riverine floods and landslides affect transportation negatively ▪ Increased heat spells will damage railway tracks	▪ Thawing of permafrost will affect foundations, pipelines, road and railway embankments ▪ Less reliable supplies of water for urban water systems ▪ Coastal areas and erosion and flooding

[35] Boko et al. 2007; EPA 2007 http://www.epa.gov/climatechange/index.html

Health	▪ Severe heat waves will intensify in magnitude and duration over the portions of U.S. and Canada where they already occur ▪ Surface ozone concentration will increase in a warmer climate => risks to people with asthma and lung diseases ▪ Increased pollen in air ▪ The northern range for the tick carrying Lyme disease could shift north by 200 km by the 202s, 1000 km by 2080s	▪ Increased risk of severe heat waves and adverse health effects especially in cities
Tourism	▪ Coastal tourism areas vulnerable to sea level rise ▪ Climate induced environmental changes would affect nature-based tourism ▪ Risks for ski industry – without snowmaking the ski season in western North America will likely shorten substantially (3-6- weeks 2050s; 7-15 weeks 2080s) ▪ Snowmobiling industry most vulnerable	
Coastal areas and lowlands	▪ Rapid coastal development reduces the effectiveness of natural protective features in the coastal zone.	

Table A 3 Projected climate change impacts in Latin America[36]

Sector	Impacts	Hot spots/ vulnerabilities
Water resources, aquatic ecosystems	▪ Number of people to experience increased water stress is estimated to range from 12 to 81 million in 2020s, 79-178 million in the 2050s. ▪ Current vulnerabilities will be increased by growing water demands due to an increasing population rate, and the future drier conditions in many basins. ▪ On going rapid glacier recession is projected to continue and cause enhanced discharge at the expense of catchment storage ▪ Reduction of glaciers will effect water availability in Colombia (2015-2025) and could impact availability of water supply for 60% of the population of Peru. ▪ In Ecuador, 7 of the 11 principal basins would be affected by a decrease in annual runoffs ▪ Under severe dry conditions, combined with deforestation, soil erosion and abusive use of agrochemicals, surface and groundwater quality will deteriorate in Nicaragua, Costa Rica, Central Valley rivers in Central America, Magdalena river in Columbia, Rapel river in Chile, and Uruguay river.	▪ Severe water stresses could be expected in east Central America, in the plains, Montagua valley and Pacific slopes of Guatemala, east and western regions of El Salvador, the Central Valley ad Pacific region of Costa Rica, in the northern, central and western intermountain regions of Honduras and in the peninsula of Azuero in Panama ▪ Increasing risk of landslides and mudflows ▪ Reduction of glaciers could severely affect the availability of water resources for mlllions of people, particularly during dry periods. Among the Andean countries, at risk are Bolivia, Ecuador, and Peru ▪ More run-off in north-western South America and less runoff in Central America
Agriculture	▪ All over the region, rice yields are projected to decrease after 2010. For smallholders, a reduction of 10% in maize yields is expected by 2055. Venezuelan piedmont yields are predicted to decline almost to zero by 2055 ▪ In Mexico grain yield could be reduced by 30% ; in Argentina grain yield could be increased by 5% (2080) (CO_2 effects considered) ▪ An increase of heat stress and more dry soils may reduce yields to 1/3 in tropic and subtropic areas ▪ In drier areas of L America, salinisation and desertification of agricultural lands is likely with climate change. By 2050, 50% of agricultural lands in L America will be affected ▪ Reduction of suitable lands for coffee in Brazil, and a reduction in coffee production in Mexico expected ▪ Soybean yields are expected to increase when CO_2 effects are considered (after 2010) ▪ In temperate areas as Argentinean and Uruguayan pampas, pastures productivity could increase 1-9% (A2, 2020) ▪ Risks of pests and diseases increases	▪ Reduction in yields in parts of the continent. More heat stress and drier soils ▪ Salinisation and desertification of agricultural lands

[36] Sources: Arnell 2004, 26; Caceres 2004, 27; UNEP 2003, 27; UNEP 2007, 141; ECLAC 2002, Ramirez et al 2001, 27; UNMSM 2005, 27

Forests	▪ By 2050 (increase of 2ºC of surface temperature, A2), potentially 24% of 138 tree species of the Central Brazil savannas (Cerrados) could become extinct. By the end of the century, 43% of 69 studied tree species could become extinct in Amazonia. ▪ A tendency of savannisation indicated for eastern Amazonia and the tropical forests of central and the south of Mexico.	▪ High risk of forest loss shown for Central America, Amazonia ▪ More frequent wild fires projected for Amazonia and much of South America (for temperature increase of over 3ºC over 60% increase in wild fires).
Biodiversity	▪ In terms of species and biome distributions, larger impacts would occur over northeast Amazonia than over western Amazonia. ▪ In Northeast Brazil and central and northern Mexico, semi-arid vegetation would be replaced by vegetation of arid regions (by end of century) ▪ Mountain cloudy forests will be threatened if temperature increases 1-2ºC during the next 50 years ▪ In Mexico, species extinction could sharply increase	▪ 40% of Amazonian forests could react drastically even to a slight reduction of precipitation ▪ The risks of forest loss in some parts of Amazonia exceed 40% for increases of temperature over 3ºC ▪ Forests can be replaced by ecosystems that have more resistance to multiple stresses caused by temperature increase, droughts and fires, such as tropical savannas
Energy	▪ Hydropower production will be affected by the reduction of glaciers, especially in Peru (UNMSM 2005, p. 27)	
Coastal areas and lowlands	▪ Significant impacts of projected climate change and sea-level rise are expected for 2050-2080 on the Latin American coastal areas. Coastal areas will be very likely to suffer floods, erosion and salinisation of lowlands, with high impacts on people, resources and economic activities.	

Table A 4 Projected climate change impacts in Africa[37]

Sector	Impacts	Hot spots/ vulnerabilities
Water resources, aquatic ecosystems	▪ Population at increased risk of water stress in Africa : by 2020s 75-250 million; by 2050s 350-600 million. Likely increase in water stress in northern and southern Africa; a reduction in water stress in eastern and western Africa ▪ In southern Africa, almost all countries except South Africa, will likely experience significant reduction in stream flow	▪ Water stress increases in Northern and Southern Africa (2055).
Agriculture	▪ Mixed rain-fed semi-arid systems in the Sahel, mixed rain-fed and highland perennial systems in the Great Lakes region and in other parts of East Africa negatively affected (A1, B1). 2000-2020 in Southern Africa, deficiencies in yields from rain-based agriculture could be up to 50%. By 2080, a significant decrease in suitable rain-fed land extent and production potential of cereals are projected ▪ Marginal agricultural areas become more marginal, moderate impacts on coastal systems (B1) ▪ Arid and semi-arid land in Africa could increase by 5-8% (60-90 million ha) by 2080 ▪ Growing seasons may lengthen in some areas (Ethiopian highlands) ▪ Reduction in frost on the alpine zones of Mt. Kenya and Mt. Kilimanjaro => possibility to grow more temperate crops	▪ Parts of Sahara will likely emerge as the most vulnerable, West Africa and central Africa are also vulnerable ▪ (2080) significant decrease in rain-fed land extent ▪ In Egypt, climate change could decrease national production of many crops (-11% for rice, -28% for soybeans) by year 2050
Biodiversity	▪ Estimated 5000 plants impacted, for 81-97% of which substantial reductions in areas of suitable climate ▪ Mountain ecosystems are already undergoing significant changes, by 2020 ice cap on Mt. Kilimanjaro could disappear ▪ Species range shifts expected, changes in tree productivity ▪ Notable changes for grasslands ▪ Disappearance of low-lying corals and losses in biodiversity expected	▪ For Fynbos and succulent Karoo biomes, 51-61% losses estimated by 2050 ▪ Losses of nyala and zebra (Malawi), losses of greater than 50% of some species in Kruger park, South Africa projected ▪ Projected losses of over 50% for some bird species by 2050 (A2) ▪ Mangroves and coral reefs negatively affected by climate change
Settlements, Transport	▪ Storm surges, flash floods and tropical cyclones coupled with localized population concentrations could impose threats ▪ Coastal settelements affected	▪ Negative impacts of climate change could create a new set of refugees => migration into new settlements and change into new livelihoods, repetitive migration, short-term migration ▪ Coastal megacities affected
Health	▪ For countries that currently have a limited capacity to control malaria, additional populations could be at risk of the disease. Previously unsuitable areas could become suitable for transmission due to changing climate conditions and create possibilities for malaria epidemics	▪ Tens of millions of additional people could be at risk of malaria by the 2080s
Tourism	▪ Very few assessments available ▪ It is likely that flood risks and water pollution related diseases in low lying regions, coral bleaching could negatively affect tourism	
Mountain ecosystems	▪ Mountain ecosystems affected, already significant changes observed	

[37] Sources: IRI 2007;, Stern 2006; IPCC 2007; van Lieshout et al. 2004;

Coastal areas and lowlands	▪ Highly productive ecosystems (mangroves, estuaries, deltas, coral reefs) are located in the coastal zone ▪ 40% of population of West Africa live in coastal cities, by 2015 3 coastal mega cities of at least 8 million people will be located in Africa ▪ Potential flood risk areas by 2080 in coastal and deltaic areas: North Africa, West Africa, southern Africa	▪ Mangroves and coral reefs negatively affected ▪ It is expected that 500 km coastline between Accra and the Niger delta will become a continuous megalopolis of more than 500 million people by 2020 => concentration of poor people in potentially hazardous areas => increased vulnerability ▪ Cities like Lagos and Alexandria will likely be impacted ▪ Flood risks increase

Table A 5 Projected climate change impacts in Asia[38]

Sector	Impacts	Hot spots/ vulnerabilities
Water resources, aquatic ecosystems	▪ The Himalayas-Hindu Kush, Kunlun Shan, Pamir and Tien Shan mountain ranges provide water to people through much of Asia – the glaciers and snow cover are projected to diminish greatly affecting water supply ▪ Variability of river runoff is projected to change in some parts of Russia; extremely low runoff may occur much more frequently in south-western crop growing regions. ▪ In Lebanon, net usable water resources will likely decrease by 15% for a temperature rise of 1.2ºC (2 x CO_2), while the flows of rivers are expected to increase in winter and decrease in spring. ▪ In the Mekong basin, increased flood risks during wet season and increased possibility of water shortage during dry season are projected ▪ Permafrost thawing on well-drained portions of slopes and highlands in Russia and Mongolia will improve the drainage conditions and lead to a decrease in the ground water content.	▪ the Mekong: increased risk of flooding during the wet season and increased possibility of water shortage during dry season (2010-38, 2070-2099) ▪ Melting of glaciers could seriously affect 0.5 billion people in the Himalaya-Hindu-Kush region and 0.25 billion people in China who depend on glacial melt for their water ▪ Increased risk of glacial lake outburst floods in the Himalayas
Agriculture	▪ By the end of this century: crop yields could increase up to 20% in E and SE Asia, rise production could decline by 3.8%. Grain and fodder productions could decrease by 26% and 9% in N Asia. ▪ Substantial losses are likely in rain-fed wheat in S and SE Asia. A 2ºC increase in mean air temperature could decrease rain-fed rice yields by 5-12% in China. In S Asia, drop in yields for non-irrigated wheat and rise will be significant for a temperature increase beyond 2.5ºC ▪ Agricultural irrigation demand in arid and semi-arid regions of Asia is estimated to increase at least 10% for increase in temperature of 1ºC. ▪ A northward shift of agricultural zones is likely => shrinking of the high mountainous and forest steppe zones and expansion of the steppe and desert steppe. Cool temperate grassland is projected to shift northward and the net primary productivity will decline. ▪ Limited fodder production, heat stress, limited water intake=> reduced milk yields and increased incidence of some diseases. ▪ Arctic marine fishery would be greatly influenced. Moderate warming is likely to improve conditions for some fisheries (cod, herring). Higher temperatures and reduced ice cover would increase productivity of fish-prey. Northern shrimp will likely decrease with rise in sea surface temperatures.	▪ Substantial decreases in cereal production potential likely by the end of 21st century but regional differences in response of wheat, maize, rice yields are great ▪ Decrease in crop yields up to 30% in C. and S Asia. Net cereal production in S Asian countries in projected to decline at least 4-10% by the end of 21st century ▪ In Bangladesh, decline in production of rise (8%) and wheat (32%) by 2050 ▪ A reduction of primary production in the tropical oceans => potentially large changes in production of fish. Also Arctic marine fishery could be greatly influenced ▪ Grasslands, livestock and water resources in marginal areas of central and SE Asia are likely to be vulnerable. Food insecurity and loss of livelihood likely to be further exacerbated by the loss of cultivated land and nursery areas for fisheries by inundation and coastal erosion in low-lying areas of tropical Asia.
Forests	▪ About 90% of the suitable habitat for dominant forest species in Japan, becch tree, could disappear by the end of the 21st century ▪ Possibility of increased risk of intensity and spread of forest fires in N and SE Asia. For an average temperature increase of 1ºC the duration of wild fire season in N Asia could increase by 30%	▪ Increased risk of wild fires

[38] Sources: IPCC 2007; UNDP 2007, 130-131; Bajracharya et al. 2007

Settlements, Transport	▪ Cities are vulnerable to higher temperatures due to urban heat island effect ▪ Vulnerabilities of megacities of Asia need to be assessed in terms of energy, communication, transport, water run-off, water quality, interrelatedness of these systems and implications for public health	▪ Megacities and flooding
Mountain ecosystems	▪ For a rise in surface temperature of 3 ºC and no change in precipitation, most Tibetan Plateau glaciers of shorter than 4 km in length are projected to disappear and the glacier areas in the Changjiang Rivers will likely decrease by more than 60%.	
Coastal areas and lowlands	▪ In some coastal areas of Asia, a 30 cm rise in sea level can result in 45 m of landward erosion. Climate change and sea level rise will tend to worsen the currently eroding coasts. ▪ In Boreal Asia, rising sea level and declining sea ice will allow higher wave and storm surge to hit the shore => enhanced coastal erosion ▪ Many mega cities in Asia are located on deltas and are subject to threats sea level rise and extreme climate events. ▪ Between 24 and 30% of coral reefs in Asia are projected to be lost during the 2-10 years and 10-30 years respectively. The loss could be as high as 88% (without conservation measures)	▪ Projected sea level rise could flood the residence of millions of people living in the low lying areas of S, SE, and E Asia (Vietnam, Bangladesh, India, China). A 40 cm rise in sea level by the end of the 21st century is projected to increase the annual number of people flooded in coastal population from 13 million to 94 million. Almost 60% of this increase will occur in S Asia (Pakistan, India, Sri Lanka, Bangladesh to Burma), while about 20% occur in SE Asia (From Thailand to Vietnam)

Table A 6 Projected climate change impacts in the Arctic[39]

Sector	Impacts	Hot spots/ vulnerabilities
Snow and ice	▪ A shortened snow season in the Arctic for the late 21st century predicted, the largest actual decrease in snow cover in spring ▪ A substantial retreat of Arctic sea ice in summer projected throughout the Arctic Ocean and sea ice cover is likely to be thinner ▪ Thawing of permafrost (=> increase nutrient, sediment and carbon loadings to water systems, enhancing productivity in nutrient-limited systems; increased surface waters drain to groundwater systems leading to losses of freshwater habitat) ▪ Thawing permafrost causes instability of landscape, leading to surface settlement and slope collapse => severe risks to infrastructure, offshore engineering affected as well as containment structures	▪ Changes in reflectivity of snow and ice and vegetation; changes of albedo may lead to further climate change ▪ Thawing of permafrost ▪ Possible release of methane from methane hydrates ▪ Melting of Arctic Sea Ice
Water resources, aquatic ecosystems	▪ Increases in flow for the major arctic river systems, with largest increases in winter; flows could decrease in summer ▪ Total annual inflow to the Arctic Ocean expected to increase 10-30% by late 21st century ▪ Reductions in river and lake ice-covers due to warming => thermal structures affected ▪ Ice-jamming and related floods could increase ▪ Drying of ponds and wetlands ▪ Destabilisation of banks and slopes and consequently increased erosion and sediment supply to rivers	▪ Increased river inflow to Arctic Ocean could affect the thermohaline circulation
Agriculture	▪ The northern limit of agriculture may shift to north by mid-century by few hundreds of km in Siberia	
Forests	▪ Treeline advance about 2 km/year estimated ▪ Forest replaces tundra, 10-50% replacement by 2100 ▪ With 1-3º C warming plant communities respond rapidly, shrub growth increases, species diversity decreases initially	▪ Climate warming will decrease the reflectivity of the land surface due to expansion of shrubs and trees into tundra ▪ Arctic could become either a sink or a source of carbon
Biodiversity	▪ Migrating species rely on the existence of specific polar habitats => communities and foodwebs throughout the Arctic affected ▪ Dispersal and geographical distribution patterns of aquatic species will be altered, particularly for fish (lake trout and other cold water species) ▪ Enhanced sediment loadings will negatively affect benthic and fish-spawning habitats, and contribute to habitat loss by filling ▪ New parasites/diseases may appear ▪ Southerly species will likely colonize Arctic areas resulting in new assemblages ▪ Tundra is projected to replace about 15-25% o the polar desert, net primary production will increase by about 70% ▪ Arctic animals are likely to be most vulnerable to warming induced drying, changes in snow cover and freeze-thaw cycles, influx of new competitors, predators, parasites and diseases ▪ Commercial fish stocks in the Arctic seas benefit from increase in open water and higher production of the sea	▪ Large mammals affected negatively (polar bear, seals, walrus) ▪ Distribution and abundance of crustaceans and fish at the sea-ice edge affected => negative impacts to other predators such as seals, sea birds and polar bears. ▪ Cold water fish species may lose habitat ▪ Changes in snow affects ecosystems through changes in growth season, snow insulation, runoff pulses, structure of snow cover and ice layeers

[39] Sources: IPCC 2007; UNEP 2007; ACIA 2005

Energy	▪ Reduction in the demand for heating energy ▪ Thawing permafrost affects pipelines	▪ Risks of pipeline failures increase
Transport	▪ Thawing permafrost affects roads and structures ▪ By 2041-2060, most of the alternative routes in the Northwest Passage and Northern Sea Route are projected to be nearly ice-free. By the end of the century, vast areas of the Arctic Ocean are projected to be ice-free in summer.	
Coastal areas and lowlands	▪ Increased erosion in coastal areas (thawing permafrost	▪ Coastal erosion will introduce greater sediment loads to the coastal system and increase emissions of CO_2 and CH_4