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REGIONAL CHALLENGES IN THE PERSPECTIVE OF 2020

REGIONAL DESPARITIES AND FUTURE CHALLENGES

A report to the Directorate-General for Regional Policy

Unit Conception, forward studies, impact assessment

BACKGROUND PAPER ON:

Climate Change

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1 SYNTHESIS

Climate change is a serious issue and will have severe and at the same time heterogeneous effects on the countries in the world. While some countries (as e.g. Russia, the Nordic countries) might benefit, provided that temperature increases are not too high, many countries, amongst them the poorest countries in the world will face severe negative impacts. A main point of concern for any country is that climate change is a multidimensional phenomenon, and as such its negative effects could be much harder than the effects of any other challenge.

Global impacts

At the global level the key vulnerabilities are water, food, health, land, environment, infrastructure and the increase in extreme weather events.

The impact of climate change is most strongly felt through changes in the distribution of water around the world and differences in water availability between regions will become increasingly pronounced. Certain areas like the Mediterranean, Southern Africa and South America, are likely to experience further decreases in water availability, while by South Asia and parts of Northern Europe and Russia are likely to experience increases in water availability.

Global warming will lead to substantial declines in cereal production around the world, especially in Africa and Western Asia, while in higher-latitude developed countries agricultural yields eventually might increase, given that the temperature increase is moderate.

Human health will be strongly affected by climate change will, as worldwide deaths from malnutrition and heat stress are likely to increase and vector-borne diseases could become more widespread.

A rising sea levels will increase the amount of land lost and people displaced due to permanent inundation. A sea level rise might also have some major impacts on national and even the global economy, as coastal areas are not only amongst the most densely populated areas, but in many cases are the location of critical infrastructure (e.g. oil refineries, industrial facilities etc.).

As climate change is likely to increase the intensity of storms, infrastructure damage costs will increase substantially, and moreover, storms and associated flooding are already the most costly natural disaster today, making up almost 90% of the total losses from natural catastrophes in 2005.

Climate change will also have severe consequences for many species as it will accelerate species extinctions and has the potential to lead to the irreversible loss of many species around the world.

European impacts

As any other part of the world Europe will be affected by climate change. Hence, given the multidimensional characteristics Europe will be faced with not only one challenge but with a huge numbers of challenges related to climate change simultaneously. At the same time, the impacts of these challenges, covering major economic, social and environmental aspects, are unequally distributed over the 5 European climate regions. Thus, the impact will be highest in Southern regions and gradually decline to the North.

The warming trend throughout Europe is well established, on average temperature increased for the European land area up to 2007 by 1.2 °C above pre-industrial levels. Moreover, eight of the 12 years between 1996 and 2007 were among the 12 warmest years since 1850. Projections suggest that warming is to be greatest over eastern Europe in winter and over western and southern Europe in summer. A very large increase in summer temperatures is expected to occur in the south-western parts of Europe, exceeding 6°C in parts of France and the Iberian Peninsula. Mean annual precipitation is expected to increase in northern

Europe and to decrease further south. Extreme events like hot days, tropical nights, and heat waves have become more frequent and are likely to occur even more often in the future.

Environmental vulnerabilities

As far as water is concerned, climate change may result in increased threats to the ecological status of lakes and enhanced health risks. At the same time strong changes in the seasonality of river flows across Europe are expected and regions in southern Europe which already suffer most from water stress are projected to be particularly vulnerable to reductions in water resources due to climate change. Moreover, changes in the water cycle are likely to increase the risk of floods and droughts, especially in northern, central and eastern Europe, while the risk of drought increases mainly in southern Europe. Increase in intense short-duration precipitation in most of Europe is likely to lead to increased risk of flash floods.

For European coastal areas the projections a significant rise of the sea-level, causing flooding, land loss, the salinisation of groundwater and the destruction of built property and infrastructures. It is projected that up to an additional 1.6 million people each year in the Mediterranean, northern and western Europe.

The melting of glaciers will cause natural hazards and damage to infrastructure and changes in river flows and seasonality, thus substantially affecting the hydrological cycle in river catchment areas. In the future the duration of snow cover is expected to decrease by several weeks for each °C of temperature increase in the Alps region.. Glaciers will experience a substantial retreat during the 21st century and small glaciers will disappear, while larger glaciers will suffer a volume reduction between 30% and 70% by 2050.

Climate change is affecting the physiology, phenology and distribution of European plant and animal species. Some models indicate that more than half of the plant species could become vulnerable, endangered, critically endangered or committed to extinction by 2080. The range of plants is very likely to expand northward and contract in southern European mountains and in the Mediterranean Basin.

Economic and social impacts

The effects of climate change and increased atmospheric CO2 are expected to lead to overall small increases in European crop productivity. Climate-related increases in crop yields are expected mainly in northern Europe, while the largest reductions of all crops are expected in the Mediterranean, the south-west Balkans and in the south of European Russia.

Under future climate change, demand for heating decreases and demand for cooling increases. relative to 1961 to 1990 levels. In the UK and Russia, a 2°C warming by 2050 is estimated to decrease space heating needs in winter, thus decreasing fossil fuel demand by 5 to 10% and electricity demand by 1 to 3%. Wintertime heating demand in Hungary and Romania is expected to decrease by 6 to 8% and by 10% in Finland by the period 2021 to 2050. Around the Mediterranean, two to three fewer weeks a year will require heating but an additional two to three (along the coast) to five weeks (inland areas) will need cooling by 2050, which will lead to an up to 10% decrease in energy heating requirements and up to 28% increase in cooling requirements in 2030 for the south-east Mediterranean region.

Conditions for tourism are expected to improve in northern and western Europe. Higher summer temperatures may lead to a gradual decrease in summer tourism in the Mediterranean but an increase in spring and perhaps autumn and it is shown that Greece and Spain will experience a lengthening and a flattening of their tourism season. The ski industry in central Europe is likely to be disrupted by significant reductions in natural snow cover.

Over the next century, heat-waves are very likely to become more common and severe causing more heat-related deaths, even after assuming acclimatisation. Cold mortality is a problem in mid-latitudes but is likely to decline with milder winters. Climate change is likely to increase the risk of mortality and injury from wind storms, flash floods and coastal flooding. Moreover, a number of vector-borne diseases are expected to increase in the near future. Climate change is also likely to affect water quality and quantity in Europe, and hence the risk of contamination of public and private water supplies.

The urban heat island effect means that urban areas can experience higher temperatures than more rural counterparts, making overheating more pronounced in cities, potentially increasing the number of excess deaths, particularly of vulnerable people, a reduction in the comfort of urban residents, and an increased demand for air conditioners, thus increasing energy requirement and further exacerbating climate change.

Overall it is expected that climate change implies huge economic costs, but though costs and potential benefits of climate impacts have been quantified, other factors than climate change often have a dominant effect, so that these assessments are to a large extent uncertain.

Global spillovers on Europe

Global effects of climate change can have some repercussions on Europe. Thus at higher temperatures, Europe and other developed economies face a growing risk of large-scale shocks. Extreme weather events could affect trade and global financial markets through disruptions to communications and more volatile costs of insurance and capital. Likewise major areas of the world could be devastated by the social and economic consequences of very high temperatures. As history shows, this could lead to large-scale and disruptive population movement and trigger regional conflict. From that climate change increases migratory pressures on developed countries significantly. Additionally the EU and other developed countries may become drawn into climate-induced conflicts in regions that are hardest hit by the impacts, particularly as the world becomes increasingly interconnected. Direct conflict between nation states because of water scarcity has been rare in the past, but can increase in the future.

Vulnerability of EU NUTS2 regions

To analyse the impact of climate change on the EU NUTS-2 regions an index was constructed, employing information on the regions vulnerability to droughts and floods, potential effects on agriculture, fisheries and tourism as well as urban and coastal areas, taking into account temperature and precipitation changes. Furthermore GDP per head is used to proxy the adaptation potential of the regions.

With this index the EU NUTS-2 regions were divided in 3 groups according to their vulnerability to climate change.

The regions with high vulnerability are mainly coastal regions, located either located at the Mediterranean sea or at the Black and North Sea. Regions with medium vulnerability are spread all over Europe (except the North), especially in the UK, France and Italy, Central and Eastern Europe (including Austria) and the Northern parts of Spain and Germany as well as Denmark. Regions with low vulnerability are geographically more concentrated, mostly in Central Europe (Germany, Eastern parts of France, Southern part of Belgium) and Northern Europe (Scandinavia, the Baltics and also main areas in Poland). Despite their low vulnerability, if compared to other regions, these regions are not immune to climate change.

Regional Scenarios

The analysis of the impacts of the climate change challenge on regional disparities within the EU will be done with two alternative scenarios; the first assumes that climate change causes a continuous increase of the temperature, while the second assumes that climate change effects (at least up to 2020) mainly will be felt through a higher number of extreme events.

The analysis of the first scenario suggests that a steady increase in temperature has –at least up to the year 2020 – a relatively weak impact on the EU regions. Impacts will be felt most in the coastal and/or Mediterranean and Black Sea regions as well as Southern Hungarian regions as well as in Central and Eastern European regions, because of their low income levels and the inferred lack of adaptation potential.

By contrast, in the first scenario most European regions are considered to be low vulnerable, and though they might be affected by climate change, the potential impacts should be manageable with some adaption efforts. This is especially the case, since most climate models predict that up to 2020 the increase global temperature is rather modest (0.5°C) and hence the negative impacts limited.

The analysis of the second scenario reveals, by putting a focus on extreme events, a significant change of the perception of the regions vulnerability to climate change. In fact all but a few regions in the EU are likely to suffer to a considerable extent from extreme events. Vulnerability is highest in the Southern regions, as well as in most Central and Eastern European regions, partly because of their low adaptation potential. Vulnerability is also high in the North of France and Germany and in the Southern parts of the UK. While the most of the Northern regions, including Poland, are potentially vulnerable to floods and storms, the Southern regions, are also vulnerable to floods but at the same time to droughts, as the seasonal variability of rainfall increases in the winter, while heatwaves will get stronger during the summer months, carrying with them all the negative consequences described in detail above. The importance of taking into account extreme events, when analysing the effects of climate change, is also shown by the large number of central regions that are medium vulnerable, at least as defined as by the index in use. Thus, virtually all, but few EU regions are either highly or medium vulnerable to extreme events.

As a consequence, the perception of climate change differs widely depending on whether it is assumed that global warming will be a continuous process, without major changes in the climate variability, or whether global warming causes a higher frequency of extreme weather events. The existing evidence and climate models suggest that climate change will and already is in fact a mixture of both, though there is potentially a difference in the timing. The negative effects of extreme events are likely to occur in higher number much sooner, while the temperature is expected to increase relatively slowly and hence negative impacts will be felt later in the future.

For that action to combat climate change is needed already now. This is obvious for mitigation issues as any measures taken now, though already being late, serve to reduce the negative impacts in the future. It might be less obvious for adaptation measures, but considering that extreme events will strike most EU regions already in the near future, leaves no doubt that we have to be prepared as good and as soon as possible to prevent major damage to our economy, environment and lives.

2 Introduction

2.1 Goals of the analysis

Outline

The present paper provides a concise analysis of the potential impact of climate change to generate or reduce regional income disparities in Europe and on the role of neighbouring countries in this process, in the perspective of 2020. The paper aims to stimulate a discussion, involving international institutions as well as independent experts, from which two opposite scenarios will be produced.

The analysis is part of a broader project of DG REGIO, which, together with the World Bank and the Bertelsmann Foundation, has established the Regional Future Initiative, a network of experts looking at the future of regional trends. The objective of the network is to analyse and build a consensus on the future impacts of key challenges (globalisation, climate change, demographic change and migration, energy risks and social polarisation) that regions will face in the perspective of 2020 and to elaborate and discuss possible responses. The output of the network should provide a basis for policy discussion and choices in the coming years.

The present paper is based upon the analysis produced by Regional Future network itself, international institutions and scholars. Since the project will carry out five seminars, the discussion on each of the five challenges is as much as possible designed to avoid a too wide overlapping among the subjects. In the final phase each challenge analysis will be merged to produce two general scenarios.

Climate change

In this paper climate change is understood as a set of alterations in the average weather caused by global warming due to the emission of anthropogenic greenhouse gases.

Climate change is serious and scary. Amongst all challenges that are dealt with in this project it is the one challenge that potentially has the most severe impacts, globally and on Europe. The very reason for this is that climate change affects virtually every aspect of our every day life, economic, social and environmental. It is a multidimensional challenge, with its impacts not only ranging from issues like human health, supply of safe water and food, biodiversity, economic development etc., but also has impacts on all the other four challenges dealt with under this project.

The impacts of climate change can be extreme, almost unbelievable. To illustrate, pessimistic estimates predict that if global temperature increases by around 3°C above pre-industrial level additional 550 million people (approximately the size of the EU) will be at risk of hunger in world. Likewise, for the same increase in temperature, 50% of animal species may be extinct, and this is just the top of the (by then non-existing) iceberg.

Climate change is not an European challenge. It is a global challenge with effects on Europe. This has to be made aware of. Because just as Europe is responsible for safeguarding its people from the negative impacts of climate change, it has, being one of the world's major force, to take up its responsibility for the other parts of the world. It is certainly not enough to sit back and enjoy the privilege of being born into a developed part of the world that, if let alone, could deal with any problem or challenge. Our actions affect people all over the world, just as their actions affect us. From that, if philanthropist reasons are not enough for Europe to take up its responsibility, it should do so, because the impacts climate change has in other parts of the world might have military, social and economic repercussions on the Europeans.

In the light of the severity of the impacts climate change can have, it is surprising how little is known about it in public. Sure, climate change gained public attention in 2007, when Al Gore and the IPCC won the Nobel

Peace Prize "for their efforts to build up and disseminate greater knowledge about man-made climate change, and to lay the foundations for the measures that are needed to counteract such change". But still it is felt that public awareness is much too low.

Tackling climate change and finding the right policies is not only about mitigation, adaption and analysing the problem. It is also about making it known to the people, because in the end it is us that, with our every day actions, are responsible of what the future climate will be.

Task

In this spirit, and since climate change is, as mentioned, a multidimensional challenge this paper, by reviewing the current literature, aims at giving an overview of the multiple impacts climate change can have globally and on Europe. Its main focus are the economic, environmental and social consequences, firstly at the world and secondly at the European level, with the ultimate aim to derive some conclusions on how climate change affects the European Union's NUTS-2 regions.

The remainder of the paper is organised as follows:

Chapter 2 reviews current findings on the global and European impact of climate change, also taking into account developments in neighbouring regions, likely repercussions from global effects on Europe and some aspects of adaption to climate change. Chapter 3 develops an indicator to assess the vulnerability of EU NUTS 2 regions to climate change. Finally, chapter 4 by taking into account the insights from the previous chapter the paper dares to present two scenarios of potential impacts of climate change on regions: a pessimistic scenario based on the assumption that climate change and global warming cannot be stopped and an optimistic scenario based on the hypothesis that global warming will stop at the EU's target of a temperature that is only 2°C higher than in the pre-industrial era.

Importantly, it has to be noted that mitigation will not be covered in this paper, as this will be done in the paper on the energy challenge.

3 The Climate Challenge – global and European trends

3.1 Global Challenges

Climate change is a serious issue and will have severe effects on any country in the world. Yet, analysis show that the extent of these effects differ around the global. While some countries might benefit, provided that temperature increases are not too high, many countries, amongst them the poorest countries will face severe negative impacts. For the latter countries this could mean entering a vicious circle of increasing vulnerability and poverty.

A main point of concern for any country is that climate change affects all essential parts of life and well being, water supply, food production, human health, availability of land, ecosystems, social and economic aspects. Thus, in contrast to many other challenges, dramatic changes in world climate, not only affect one or few areas of people's life at a time, rather it is a multidimensional phenomenon, and as such its negative effects could be much harder than the effects of any other challenge, as for example globalisation or energy issues. The multidimensional character of climate change is illustrated in Table 1, that present excerpt of some major consequences of climate change on various aspects, depending on the extent of the increase in global temperature is.

Table 1: Highlights of possible climate impacts

<table>
<tr><th>Temp rise (°C)</th><th>Water</th><th>Food</th><th>Health</th><th>Land</th><th>Environment</th><th>Abrupt and Large-Scale impacts</th></tr>
<tr><td>1°C</td><td>Small glaciers in the Andes disappear completely, threatening the water supplies for 50 million people</td><td>Modest increases in cereal yields in temperate regions</td><td>At least 300.000 people each year die from climate-related diseases (predominantly diarrhoea, malaria and malnutrition)

Reduction in winter mortality in higher latitudes</td><td>Permafrost thawing damages buildings and roads in Canada and Russia</td><td>At least 10% of land species facing extinction (according to one estimate)

80% bleaching of coral reefs, including Great Barrier Reef</td><td>Atlantic Thermohaline Circulation starts to weaken</td></tr>
<tr><td>2°C</td><td>Potentially 20 – 30% decrease in water availability in some vulnerable regions, e.g. Southern Africa, Mediterranean</td><td>Sharp declines in crop yield in tropical regions (5 – 10% in Africa)</td><td>40-60 million more people exposed to malaria in Africa</td><td>Up to 10 million more people affected by coastal flooding each year</td><td>15-40% of species facing extinction (according to one estimate)

High risk of extinction of Arctic species, including polar bear and caribou</td><td rowspan="4">Potential for Greenland ice sheet to begin melting irreversibly, accelerating sea level rise and committing world to an eventual 7m sea level rise

Risking of abrupt changes to atmospheric circulations, e.g. the monsoon

Rising risk of collapse of West Antarctic Ice Sheet

Rising risk of collapse of the Atlantic Thermohaline Circulation</td></tr>
<tr><td>3°C</td><td>In Southern Europe serious droughts occur once every 10 years</td><td>150-550 additional millions at risk of hunger (if carbon fertilisation weak)

Agricultural yields in higher latitudes likely to peak</td><td>1-3 million people die from malnutrition (if carbon fertilisation weak)</td><td>1-170 million more people affected by coastal flooding each year</td><td>20-50% of species facing extinction (according to one estimate), including 25-60% mammals, 30-40% birds and 15-70% butterflies in South Africa

Collapse of Amazon rainforest (according to some models)</td></tr>
<tr><td>4°C</td><td>Potentially 30-50% decrease in water availability in Southern Africa and Mediterranean</td><td>Agricultural yields decline by 15-35% in Africa, and entire regions out of production (e.g. parts of Australia)</td><td>Up to 80 million more people exposed to malaria in Africa</td><td>7-300 million more people affected by coastal flooding each year</td><td>Loss of around half Arctic tundra

Around half of all the world's nature reserves cannot fulfil objectives</td></tr>
<tr><td>5°C</td><td>Possible disappearance of large glaciers in Himalayas, affecting on quarter of China's population and hundreds of millions in India</td><td>Continued increase in ocean acidity seriously disrupting marine ecosystems and possibly fish stocks</td><td></td><td>Sea level rise threatens small islands, low-lying coastal areas (Florida) and major world cities such as New York, London, Tokyo</td><td></td></tr>
<tr><td>more than 5°C</td><td colspan="6">The latest science suggests that the Earth's average temperature will rise by even more than 5° or 6°C if emissions continue to grow and positive feedbacks amplify the warming effect of greenhouse gases (e.g. release of carbon dioxide from soils or methane from permafrost)- This level of global temperature rise would be equivalent to the amount of warming that occurred between the last age and today – and is likely to lead to major disruption and large-scale movement of population. Such "socially contingent" effects could be catastrophic, but are currently very hard to capture with current models as temperatures would be so far outside human experience.</td></tr>
</table>

Note: This table shows illustrative impacts at different degrees of warming. Some of the uncertainty is captured in the ranges shown, but there will be additional uncertainties about the exact size of impacts. Temperature represent increases relative to pre-industrial levels. At each temperature, the impacts are expressed for a 1°C band around the central temperature, e.g. 1°C represents the range 0.5°C-1.5°C. Numbers of people affected at different temperatures assume population and GDP scenarios for the 2080s from the IPCC. Figures generally assume adaption at the level of an individual or firm, but not economy-wide adaptations due to policy intervention.

Source: Stern Review Report on the Economics of Climate Change, Part II, p.57, 2007

In the following part the individual global vulnerabilities are described in more detail.[1]

3.1.1 Water

The impact of climate change is most strongly felt through changes in the distribution of water around the world and its seasonal and annual variability. Climate change will alter patterns of water availability by intensifying the water cycle. Droughts and floods will become more severe in many areas. There will be more rain at high latitudes, less rain in the dry subtropics, and uncertain but probably substantial changes in tropical areas. Hotter land surface temperatures induce more powerful evaporation and hence more intense rainfall, with increased risk of flash flooding.[2]

Differences in water availability between regions will become increasingly pronounced. Areas that are already relatively dry, such as the Mediterranean basin and parts of Southern Africa and South America, are likely to experience further decreases in water availability. Already today around one-third of today's global population live in countries experiencing moderate to high water stress, and 1.1 billion people lack access to safe water. The effects of rising temperatures are likely to cause changes in the water status of billions of people. According to one study, temperature rises of 2°C will result in 1 – 4 billion people living in dry areas experiencing growing water shortages.

By contrast, South Asia and parts of Northern Europe and Russia are likely to experience increases in water availability. These changes in the annual volume of water each region receives mask another critical element of climate change – its impact on year-to-year and seasonal variability. An increase in annual river flows is not necessarily beneficial, particularly in highly seasonal climates, because: (1) there may not be sufficient storage to hold the extra water for use during the dry season, and (2) rivers may flood more frequently.

Moreover climate change will have serious consequences for people who depend heavily on glacier meltwater to maintain supplies during the dry season, including large parts of the Indian sub-continent, over quarter of a billion people in China, and tens of millions in the Andes. For those water flows may increase in the spring as the glacier melts more rapidly, while they may face shortages later in the year. In the long run dry season water will disappear permanently once the glacier has completely melted. Parts of the developed world that rely on mountain snowmelt will also have their summer water supply affected, unless storage capacity is increased to capture the "early water".[3]

3.1.2 Food

In tropical regions, even small amounts of warming will lead to declines in yield. In higher latitudes, crop yields may increase initially for moderate increases in temperature but then fall. Higher temperatures will lead to substantial declines in cereal production around the world, particularly if the carbon fertilisation effect is smaller than expected. While agriculture in higher-latitude developed countries is likely to benefit from moderate warming (2 – 3°C), even small amounts of climate change in tropical regions will lead to declines in yield. Here crops are already close to critical temperature thresholds and many countries have limited capacity to make economy-wide adjustments to farming patterns. The impacts will be strongest across Africa and Western Asia (including the Middle East), where yields of the predominant regional crops may fall by 25 – 35% or 15 – 20% (depending on the strength of the carbon fertilisation effect) given a 3 to 4°C increase of temperature.

Expressed in numbers these trends are more than alarming. While already today around 800 million people are currently at risk of hunger and malnutrition causes around 4 million deaths annually, temperature rises of

[1] This section is based on the Stern Review Report on the Economics of Climate Change, Part II
[2] Stern Review Report, p. 62
[3] Stern Review Report, p. 63 ff.

2 to 3°C might increase the people at risk of hunger, potentially by 30 - 200 million and even to 550 million (over half in Africa and Western Asia) if the temperature increases more than 3°C. [4]

3.1.3 Health

Climate change will increase worldwide deaths from malnutrition and heat stress. Vector-borne diseases such as malaria and dengue fever could become more widespread if effective control measures are not in place. In higher latitudes, cold-related deaths will decrease. Overall, climate change will amplify health disparities between rich and poor parts of the world. It is estimated that just a 1°C increase in global temperature above pre-industrial could double annual deaths from climate change to at least 300,000 according to the WHO.

The distribution and abundance of disease vectors are closely linked to temperature and rainfall patterns. Changes to mosquito distributions and abundance will have profound impacts on malaria prevalence in affected areas. This will be particularly significant in Africa, where 450 million people are exposed to malaria today, and there are estimates that a 2°C rise in temperature may lead to 40 – 60 million more people exposed to malaria in Africa.

Health will be further affected by changes in the water cycle, as droughts and floods are harbingers of disease, as well as causing death from dehydration or drowning. Prolonged droughts will fuel forest fires that release respiratory pollutants, while floods foster growth of infectious fungal spores, create new breeding sites for disease vectors such as mosquitoes, and trigger outbreaks of water-borne diseases like cholera.[5]

3.1.4 Land

Rising sea levels will increase the amount of land lost and people displaced due to permanent inundation, while the costs of sea walls will rise approximately as a square of the required height. Coastal areas are amongst the most densely populated areas in the world and support several important ecosystems on which local communities depend. Critical infrastructure is often concentrated around coastlines, including oil refineries, nuclear power stations, port and industrial facilities. Currently, more than 200 million people live in coastal floodplains around the world, and many of the world's major cities (22 of the top 50) are at risk of flooding from coastal surges, including Tokyo, Shanghai, Hong Kong, Mumbai, Calcutta, Karachi, Buenos Aires, St Petersburg, New York, Miami and London.

Thus, sea level rises will lead to large increases in the number of people whose homes are flooded. According to some estimates between 7 – 70 million and 20 – 300 million additional people (depending on population growth) will be flooded each year by 3 to 4°C of warming causing 20 – 80 cm of sea level rise. South and East Asia will be most vulnerable because of their large coastal populations in low-lying areas, such as Vietnam, Bangladesh and parts of China and India. Millions will also be at risk around the coastline of Africa, particularly in the Nile Delta and along the west coast. Small island states in the Caribbean, and in the Indian and Pacific Oceans are acutely threatened, because of their high concentrations of development along the coast. Some estimates suggest that 150 - 200 million people may become permanently displaced by the middle of the century due to rising sea levels, more frequent floods, and more intense droughts.[6]

3.1.5 Infrastructure

As climate change is likely to increase the intensity of storms, infrastructure damage costs will increase substantially from even small increases in sea temperatures because: peak wind speeds of tropical storms

[4] Stern Review Report, p. 67 ff.
[5] Stern Review Report, p. 74 ff.
[6] Stern Review Report, p. 76 ff.

are a strongly exponential function of temperature, increasing by about 15 - 20% for a 3°C increase in tropical sea surface temperatures; and damage costs typically scale as the cube of wind-speed or more, Moreover, storms and associated flooding are already the most costly natural disaster today, making up almost 90% of the total losses from natural catastrophes in 2005. High latitude regions are already experiencing the effects of warming on previously frozen soil. Thawing weakens soil conditions and causes subsidence of buildings and infrastructure.[7]

3.1.6 Ecosystems and biodiversity

Already in 20th century global warming has directly affected ecosystems, as e.g. species have been moving polewards, and seasonal events, such as flowering or egg-laying, have been occurring several days earlier each decade. Coral bleaching has become increasingly prevalent since the 1980s. Overall it is estimated that climate change has already contributed to the extinction of over 1% of the world's amphibian species from tropical mountains.

For the future it is expected that for many species, the rate of warming will be too rapid to withstand. A warming world will accelerate species extinctions and has the potential to lead to the irreversible loss of many species around the world, with most kinds of animals and plants affected. Rising levels of carbon dioxide have some direct impacts on ecosystems and biodiversity, but increases in temperature and changes in rainfall will have even more profound effects. Vulnerable ecosystems are likely to disappear almost completely at even quite moderate levels of warming. The Arctic will be particularly hard hit, since many of its species, including polar bears and seals, will be very sensitive to the rapid warming predicted and substantial loss of sea. Expressed in numbers the estimated effects are that at a 1°C warming at least 10% of land species could be facing extinction, while at a increase of the temperature by 2°C already 15 – 40% of land species could disappear with the percentage growing the higher the temperature rise will be.[8]

3.1.7 Extreme weather events

Climate change is likely to increase the costs imposed by extreme weather, as heatwaves, severe floods, droughts and storms occur more often. Moreover the impacts of climate change will become increasingly severe at higher temperatures, particularly because of rising risks of triggering abrupt and large-scale changes, such as melting of the Greenland ice sheet or loss of the Amazon forest. The combined effect of impacts across several sectors could be very damaging and further amplify the consequences of climate change. Little work has been done to quantify these interactions, but the potential consequences could be substantial. For example, in some tropical regions, the combined effect of loss of native pollinators, greater risks of pest outbreaks, reduced water supply, and greater incidence of heatwaves could lead to much greater declines in food production than through the individual effects themselves.[9]

3.1.8 Impacts on developed and developing countries

The following Box (taken out of the Stern Review Report), summarizes the main effects of climate change for developing and developed countries.

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[7] Stern Review Report, p. 78 ff.
[8] Stern Review Report, p. 79 ff.
[9] Stern Review Report, p. 59

Box 1: Main impacts of climate change on developing and developed countries

Developing countries

- Climate change poses a real threat to the developing world. Unchecked it will become a major obstacle to continued poverty reduction. Developing countries are especially vulnerable to climate change because of their geographic exposure, low incomes, and greater reliance on climate sensitive sectors. Together these mean that impacts are proportionally greater and the ability to adapt smaller.
- Many developing countries are already struggling to cope with their current climate.
- For low-income countries, major natural disasters today can cost an average of 5% of GDP.
- Health and agricultural incomes will be under particular threat from climate change.

For example:

- Falling farm incomes will increase poverty and reduce the ability of households to invest in a better future and force them to use up meagre savings just to survive.
- Millions of people will potentially be at risk of climate-driven heat stress, flooding, malnutrition, water related disease and vector borne diseases. For example, dengue transmission in South America may increase by 2 to 5 fold by the 2050s.
- The cost of climate change in India and South East Asia could be as high as a 9-13% loss in GDP by 2100 compared with what could have been achieved in a world without climate change. Up to an additional 145-220 million people could be living on less than $2 a day and there could be an additional 165,000 to 250,000 child deaths per year in South Asia and sub-Saharan Africa by 2100 (due to income losses alone).
- Severe deterioration in the local climate could lead, in some parts of the developing world, to mass migration and conflict, especially as another 2-3 billion people are added to the developing world's population in the next few decades:
- Rising sea levels, advancing desertification and other climate-driven changes could drive millions of people to migrate: more than a fifth of Bangladesh could be under water with a 1m rise in sea levels – a possibility by the end of the century.
- Drought and other climate-related shocks risk sparking conflict and violence, with West Africa and the Nile Basin particularly vulnerable given their high water interdependence. These risks place an even greater premium on fostering growth and development to reduce the vulnerability of developing countries to climate change. However, little can now be done to change the likely adverse effects that some developing countries will face in the next few decades, and so some adaptation will be essential. Strong and early mitigation is the only way to avoid some of the more severe impacts that could occur in the second half of this century.

Developed world

- In higher latitude regions, such as Canada, Russia and Scandinavia, climate change could bring net benefits up to 2 or 3°C through higher agricultural yields, lower winter mortality, lower heating requirements, and a potential boost to tourism. But these regions will also experience the most rapid rates of warming with serious consequences for biodiversity and local livelihoods.
- Developed countries in lower latitudes will be more vulnerable. Regions where water is already scarce will face serious difficulties and rising costs. Recent studies suggest a 2°C rise in global temperatures may lead to a 20% reduction in water availability and crop yields in southern Europe and a more erratic water supply in California, as the mountain snowpack melts by 25 – 40%.
- In the USA, one study predicts a mix of costs and benefits initially (± 1% GDP), but then declines in GDP even in the most optimistic scenarios once global temperatures exceed 3°C.
- The poorest will be the most vulnerable. People on lower incomes are more likely to live in poor quality housing in higher-risk areas and have fewer financial resources to cope with climate change, including lack of comprehensive insurance cover.
- The costs of extreme weather events, such as storms, floods, droughts, and heatwaves, will increase rapidly at higher temperatures, potentially counteracting some of the early benefits of climate change. Costs of extreme weather alone could reach 0.5 - 1% of world GDP by the middle of the century, and will keep rising as the world warms.
- Damage from hurricanes and typhoons will increase substantially from even small increases in storm severity, because they scale as the cube of windspeed or more. A 5 – 10% increase in hurricane windspeed is predicted to approximately double annual damages, resulting in total losses of 0.13% of GDP each year on average in the USA alone.
- The costs of flooding in Europe are likely to increase, unless flood management is strengthened in line with the rising risk. In the UK, annual flood losses could increase from around 0.1% of GDP today to 0.2 – 0.4% of GDP once global temperature increases reach 3 to 4°C.
- Heatwaves like 2003 in Europe, when 35,000 people died and agricultural losses reached $15 billion, will be commonplace by the middle of the century.

Source Stern Review Report on the Economics of Climate Change, Part II, Chapter 4, p.92 and Chapter 5, p.1

4 European Challenges

As any other part of the world Europe will be affected by climate change. Hence, given the multidimensional characteristics Europe will be faced with not only one challenge but with a huge numbers of challenges related to climate change simultaneously. At the same time, the impacts of these challenges, covering major economic, social and environmental aspects, are unequally distributed over the 5 European climate regions. Thus, the impact will be highest in Southern regions and gradually decline the more northwards the regions are located. Therefore, regional actions and responses will play an important role in dealing with and adapting to the climate challenges.

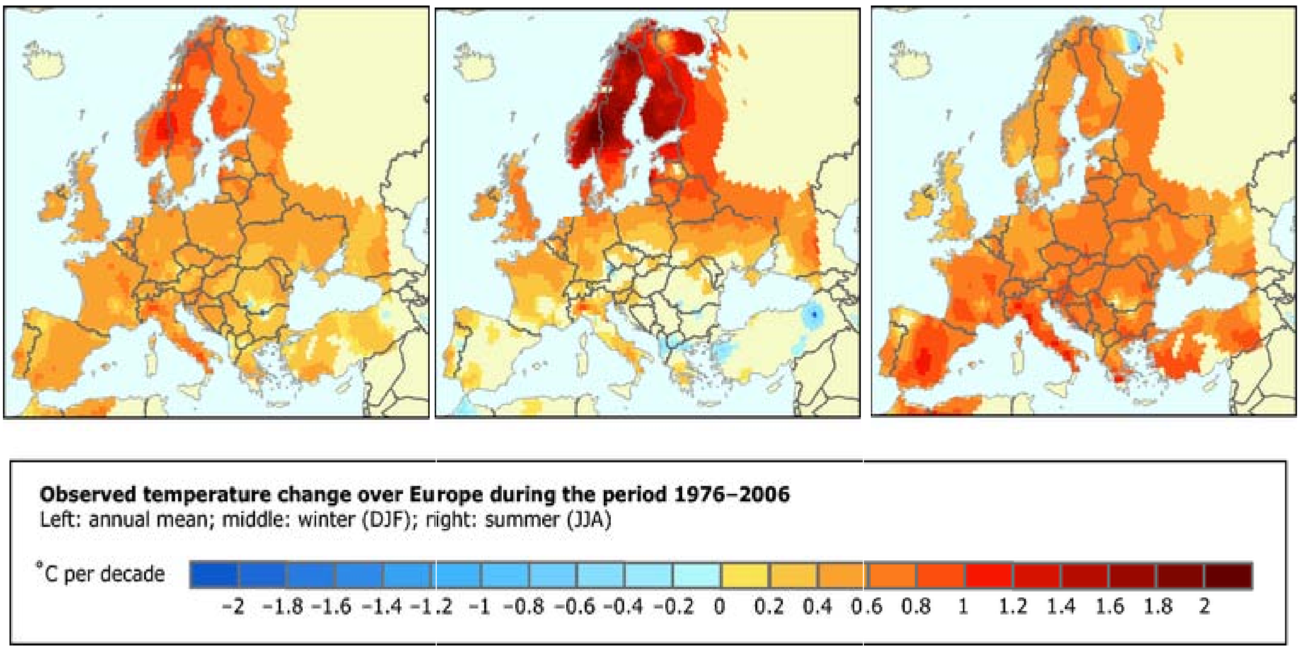
The following section now summarises the main European trends with respect to climate change as well as the main consequences that may arise. It will firstly give a short overview of current and future trends in the European climate. Secondly environmental vulnerabilities will be highlighted, followed by an analysis of the economic and social impacts. A fourth part will deal with potential spillovers of climate change effects on Europe, especially with respect to neighbouring regions and financial markets.

4.1 Current and future climate trends

4.1.1 Current climate trends

The warming trend throughout Europe is well established (+0.90°C for 1901 to 2005) though the recent period shows a trend considerably higher than the mean trend (+0.41°C/decade for the period 1979 to 2005). For the 1977 to 2000 period, trends are higher in central and north-eastern Europe and in mountainous regions, while lower trends are found in the Mediterranean region.[10] On average temperature increased for the European land area up to 2007 by 1.2 °C above pre-industrial levels, and for the combined land and ocean area 1 °C above. Eight of the 12 years between 1996 and 2007 were among the 12 warmest years since 1850.[11]

Figure 1: Temperature change in Europe, 1976-2006



[10] Alcamo, J., J.M. Moreno, B. Nováky, M. Bindi, R. Corobov, R.J.N. Devoy, C. Giannakopoulos, E. Martin, J.E. Olesen, A. Shvidenko, 2007: Europe. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment

As far as precipitation is concerned, trends in the 20th century showed an increase in northern Europe (10–40 %) and a decrease in some parts of southern Europe (up to 20 %)[12]. Still, precipitation trends are more spatially variable. Mean winter precipitation is increasing in most of Atlantic and northern Europe (20 to 40 %). In the Mediterranean area, yearly precipitation trends are negative in the east, while they are non-significant in the west. An increase in mean precipitation per wet day is observed in most parts of the continent, even in some areas which are becoming drier. Some of the European systems and sectors have shown particular sensitivity to recent trends in temperature and (to a lesser extent) precipitation.[13]

4.1.2 Future climate trends

The following section looks at 14 individual aspects of European vulnerability to climate change. To start, Table 2 present a concise summary of the results in this section.

Climate

Results presented here and in the following sections are for the period 2070 to 2099 using the climate normal period (1961 to 1990) as a baseline. From this, all IPCC emission scenarios project that Europe will face a warming in all seasons (by 2.5 to 5.5°C and 1 to 4°C depending on the model).

The warming is projected to be greatest over eastern Europe in winter and over western and southern Europe in summer, while some models also showed a larger warming in winter than in summer in northern Europe and the reverse in southern and central Europe. A very large increase in summer temperatures is expected to occur in the south-western parts of Europe, exceeding 6°C in parts of France and the Iberian Peninsula.

Generally for all scenarios, mean annual precipitation increases in northern Europe and decreases further south, whilst the change in seasonal precipitation varies substantially from season to season and across regions in response to changes in large-scale circulation and water vapour loading.

Change in mean wind speed is highly sensitive to the differences in large-scale circulation that can result between different global models. From regional simulations mean annual wind speed increases over northern Europe by about 8% and decreases over Mediterranean Europe. For France and central Europe, simulations indicate a slight increase in mean wind speeds in winter and some decrease in spring and autumn. None of the reported simulations show significant change during summer for northern Europe.[14]

Extreme events

High-temperature extremes like hot days, tropical nights, and heat waves have become more frequent, while low-temperature extremes (e.g. cold spells, frost days) have become less frequent. The average length of summer heat waves over Western Europe doubled over the period 1880 to 2005 and the frequency of hot days almost tripled.[15]

The yearly maximum temperature is expected to increase much more in southern and central Europe than in northern Europe, while at the same time the yearly minimum temperature is expected to increase across most of Europe. While this induces a decrease in winter temperature variability, the large increase in the

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Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, p. 545

[11] European Environment Agency (EEA), Joint Research Centre, World Health Organisation, 2008, Impacts of Europe's changing climate – 2008 indicator-based assessment, Chapter 5 p.41

[12] EEA, 2008, op. cit. p.45

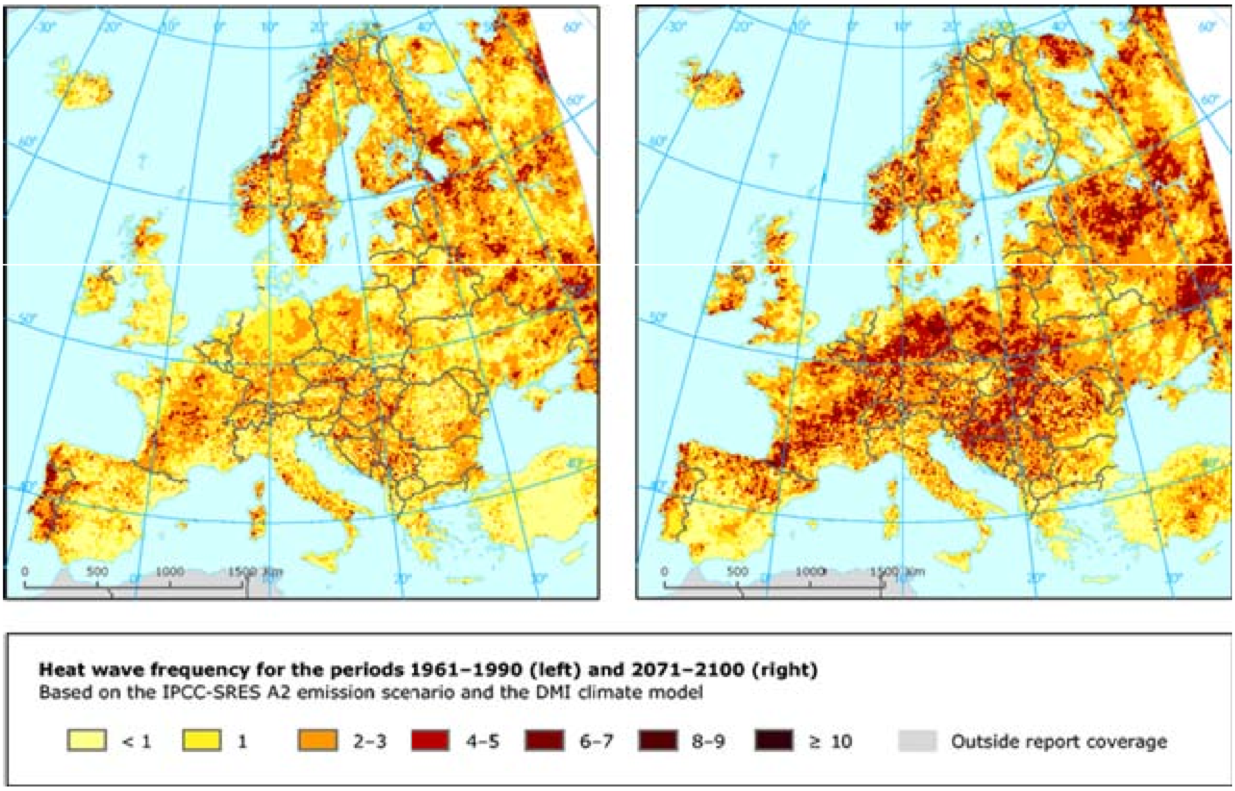
[13] Alcamo, J., et. al. ,2007, op.cit. p. 545

[14] Alcamo, J., et. al. ,2007, op.cit. p. 545

[15] EEA, 2008, op. cit. p.48

highest summer temperatures would expose Europeans to unprecedented high temperatures.[16] E.g. central Europe, is projected to experience the same number of hot days as are currently experienced in Spain and Sicily by the end of the 21st century. Likewise, night temperatures are projected to increase considerably, possibly leading to additional health problems and even mortality, at least partly compensated by reduced mortality in winter.[17]

Figure 2: Heat wave frequency



Source: EEA, 2007, Europe's Environment, The Fourth Assessment

Climate models project changes in precipitation that vary considerably from season to season and across regions. Geographically, projections indicate a general precipitation increase in northern Europe and a decrease in southern Europe. The change in annual mean between 1980–1999 and 2080–2099 projections varies from 5 to 20 % in northern Europe and from – 5 to – 30 % in southern Europe and the Mediterranean.[18] Nevertheless, it is expected that in the intensity of daily precipitation events substantially increase. This holds even for areas with a decrease in mean precipitation, such as central Europe and the Mediterranean.[19] In addition, the frequency of several-day precipitation episodes is projected to increase. Geographically, there is considerable regional differentiation in the projections. Extreme precipitation events are projected to increase by 17 % in northern and 13 % in central Europe during the 21st century, with no changes projected in southern Europe.[20]

The combined effects of warmer temperatures and reduced mean summer precipitation would enhance the occurrence of heat waves and droughts as the future European summer climate would experience a pronounced increase in year-to-year variability. The regions most affected could be the southern Iberian

[16] Alcamo, J., et. al. ,2007, op.cit. p. 548
[17] EEA, 2008, op. cit. p. 48
[18] EEA, 2008, op. cit. p. 46
[19] Alcamo, J., et. al. ,2007, op.cit. p. 548
[20] EEA, 2008, op. cit. p. 51

Peninsula, the Alps, the eastern Adriatic seaboard, and southern Greece.[21] This can be illustrated, for example, by the projected number of consecutive dry days, defined as days with precipitation below 1 mm. In southern Europe, the maximum number of these days is projected to increase substantially during the 21st century. The longest dry period within a year may be prolonged here by one month at the end of 21st century. In central Europe, prolongation of longest dry period is by one week, and no prolongation is projected for northern Europe. Thus regions in Europe that are now dry are projected to become even more vulnerable.[22]

Storms and storm surges in Europe

There has been considerable variation, but no clear long term trend in storminess in Europe. Storm frequency was relatively high during the late 19th and early 20th century; then decreased in central and northern Europe. The recent high level is similar to the late 19th century level of storminess. Still, despite the variation in storminess, water levels along most vulnerable European coastlines of the North Sea and Mediterranean Sea have shown no significant storm-related variation. Extra-tropical storm tracks are projected to move pole-wards, with consequent changes in wind, precipitation, and temperature patterns, continuing the broad pattern of observed trends over the past half-century. For the future climate models indicate a slight decrease in the number of storms and an increase of the strength of the heaviest storms.[23]

4.2 Environmental impacts and vulnerabilities

The following two sections deal with a number of key vulnerabilities with respect to climate change. The first section focuses on environmental aspects, while the second section concentrates on economic and social impacts. A summary of the main findings in both sections is presented in Table2 and Figure3.

[21] Alcamo, J., et. al. ,2007, op.cit. p. 548
[22] EEA, 2008, op. cit. p. 51
[23] EEA, 2008, op. cit. p. 54

Table 2: Overview of the main European vulnerabilities, by climate zone

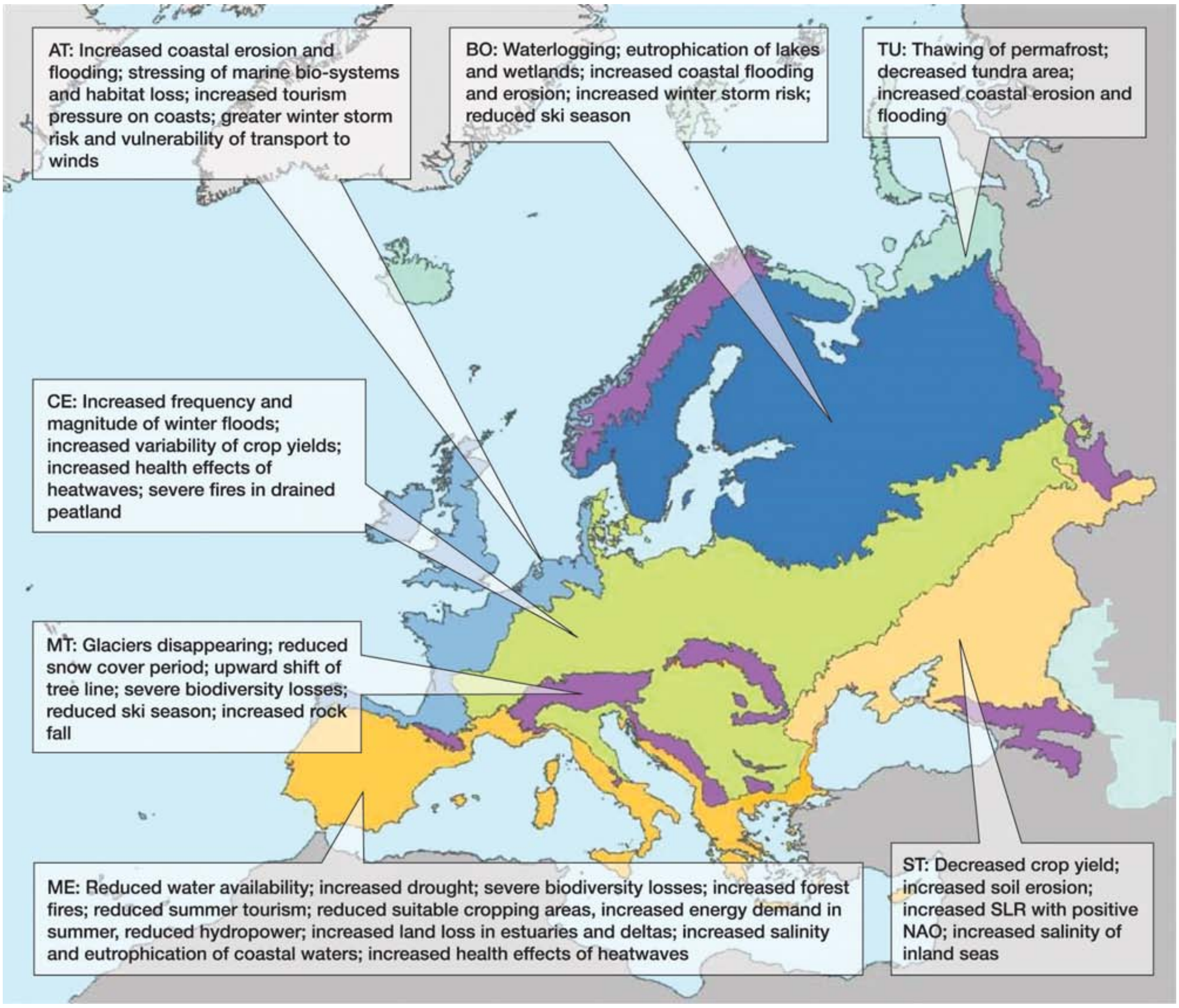
Sectors and system	Impact	North	Atlantic	Area Central	Mediterr.	East
Water resources	Floods	••	••	••	•	•••
	Water availability	••	••	•	•••	••
	Water stress	••	••	•	•••	••
Coastal and marine systems	Beach, dune: low-lying coast erosional 'coastal squeeze'	•••	•••	na	••	••
	SLR- and surge-driven flooding	•••	••	na	••	•••
	River sediment supply to estuaries and deltas	••	•	na	•••	•
	Saltwater intrusion to aquifers	•	•	na	••	•
	Northward migration of marine biota	•	•••	na	•	•
	Rising SSTs, eutrophication and stress on biosystems	•••	••	na	••	•
	Development of ICZM	••	••	na	••	•
	Deepening and larger inshore waters	••	•	na	•	••
Mountains, cryosphere	Glacier retreat	•••	•	•••	•••	•••
	Duration of snow cover	•••	•••	•••	•••	•••
	Permafrost retreat	•••	•	•	na	•
	Tree line upward shift	•••	•••	•••	•	•••
	Nival species losses	•••	•••	•••	•••	•••
Forest, shrublands and grasslands	Forest NPP	•••	••	• to •	•	• to •
	Northward/inland shift of tree species	•••	••	••	• to •	••
	Stability of forest ecosystems	••	•	•	•••	•••
	Shrublands NPP	•••	•••	•	•••	••
	Natural disturbances (e.g., fire, pests, wind-storm)	•	•	•	•••	••
	Grasslands NPP	•••	••	• to •	•••	•
Wetlands and aquatic ecosystems	Drying/transformation of wetlands	••	•	•	•••	•••
	Species diversity	• to •	•	??	••	•
	Eutrophication	•	••	••	•••	•
	Disturbance of drained peatlands	•••	•	••	na	•••
Biodiversity	Plants	••	••	••• (Mt)	•••	•
	Amphibians	••	•••	••	••• (SW) •• (SE)	•••
	Reptiles	••	••	••	••• (SW) ••• (SE)	•••
	Marine mammals	•••	??	na	•••	??
	Low-lying coastal birds	•••	•••	na	•••	??
	Freshwater biodiversity	• to •	??	??	•••	??
Agriculture and fisheries	Suitable cropping area	•••	••	•	••	•
	Agricultural land area	••	••	••	••	••
	Summer crops (maize, sunflower)	•••	••	•	•••	••
	Winter crops (winter wheat)	•••	••	• to •	•	•
	Irrigation needs	na	• to •	••	•••	•
	Energy crops	•••	••	•	••	•
	Livestock	• to •	•	••	••	••
	Marine fisheries	•	•	na	•	na
Energy and transport	Energy supply and distribution	•	••	•	•	•
	Winter energy demand	••	••	•	••	•
	Summer energy demand	•	•	••	•••	••
	Transport	•	•	•	•	•
Tourism	Winter (including ski) tourism	••	•	•••	•••	••
	Summer tourism	•	••	•	••	•
Property insurance	Flooding claims	??	••	••	??	??
	Storms claims	•	••	••	??	??
Human health	Heat-related mortality/morbidity	•	••	••	•••	••
	Cold-related mortality/morbidity	•	••	••	•	•••
	Health effects of flooding	•	••	••	••	••
	Vector-borne diseases	•	•	•	••	••
	Food safety/Water-borne diseases	•	•	•	••	••
	Atopic diseases, due to aeroallergens	•	•	•	•	•

Scoring has taken into account: a) geographical extent of impact/number of people exposed; b) intensity and severity of impact. The projected magnitude of impact increases with the number of arrows (one to three). Type of impact: positive (upward, blue); negative (downward, red); a change in the type of impact during the course of the century is marked with 'to' between arrows. na=not applicable; ??=insufficient information; North=boreal and Arctic; Central, Atlantic and Mediterranean as in Figure 12.3, including their mountains; East=steppic Russia, the Caucasus and the Caspian Sea; Mt=Mountains; SW=Southwest; SE=Southeast; SLR=Sea-Level Rise; ICZM=Integrated Coastal Zone Management; SST=Sea-Surface Temperature; NPP=Net Primary Productivity.

Source: Alcamo, J., J.M. Moreno, B. Nováky, M. Bindi, R. Corobov, R.J.N. Devoy, C. Giannakopoulos, E. Martin, J.E. Olesen, A. Shvidenko, 2007: Europe. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, p. 545

Figure 3 present a graphical summary of the key vulnerabilities in Europe.

Figure 3: Key vulnerabilities of European systems and sectors to climate change during the 21st century



Source: Alcamo, J., J.M. Moreno, B. Nováky, M. Bindi, R. Corobov, R.J.N. Devoy, C. Giannakopoulos, E. Martin, J.E. Olesen, A. Shvidenko, 2007: Europe. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, p. 558

4.2.1 Water

Over the 20th century, annual river flows showed an increasing trend in northern parts of Europe, with increases mainly in winter, and a slightly decreasing trend in southern parts of Europe. These changes are linked to observed changes in precipitation patterns and temperature.[24]

It is likely that climate change will have a range of impacts on water resources. Projections show that annual runoff increases in Atlantic and northern Europe and decreases in central, Mediterranean and eastern

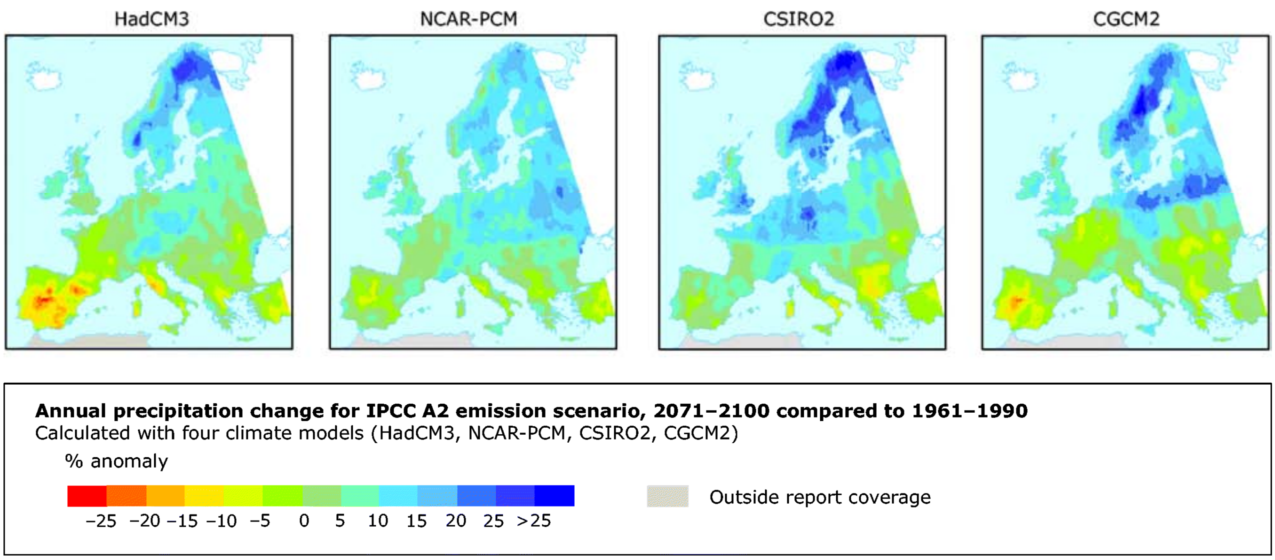
[24] EEA, 2008, op. cit. p. 93

Europe. Groundwater recharge is likely to be reduced in central and eastern Europe, with a larger reduction in valleys and lowlands (e.g., in the Hungarian steppes).[25]

Aquatic ecosystems

Increased temperatures of lakes and rivers (by 1–3 °C during the 20th century) have resulted in decreases in ice cover on lakes and rivers by 12 days on average in the last century in Europe. These changes can be at least partly attributed to climate change, and partly to other causes such as freshwater use for cooling processes (e.g. power plants).[26] Throughout Europe, in lakes and rivers that freeze in the winter, warmer temperatures may result in earlier ice melt and longer growing seasons. A consequence of these changes could be a higher risk of algal blooms and increased growth of toxic cyanobacteria in lakes. Higher precipitation and reduced frost may enhance nutrient loss from cultivated fields, likely resulting in higher nutrient loadings, which in turn may intensify the eutrophication of lakes and wetlands. Inland waters in southern Europe are likely to have lower volume and increased salinisation.[27] Climate change may thus result in increased threats to the ecological status of lakes and enhanced health risks, particularly in water bodies used for public water supply and bathing.

Figure 4 Projected precipitation change - 2100



Source: EEA, 2007, Europe's Environment, The Fourth Assessment

River flow

Climate change is projected to result in strong changes in the seasonality of river flows across Europe. Studies show an increase in winter flows and decrease in summer flows in the Rhine, Slovakian rivers, the Volga and central and eastern Europe. It is likely that glacier retreat will initially enhance summer flow in the rivers of the Alps; however, as glaciers shrink, summer flow is likely to be significantly reduced, (by up to 50%). Summer low flow may decrease by up to 50% in central Europe, and by up to 80% in some rivers in southern Europe.[28] Regions in southern Europe which already suffer most from water stress are projected to

[25] Alcamo, J., et. al. ,2007, op.cit. p. 549
[26] EEA, 2008, op. cit. p. 13
[27] Alcamo, J., et. al. ,2007, op.cit. p. 553
[28] Alcamo, J., et. al. ,2007, op.cit. p. 549

be particularly vulnerable to reductions in water resources due to climate change. This will result in increased competition for available resources.[29]

Moreover, changes in the water cycle are likely to increase the risk of floods and droughts, especially in northern, central and eastern Europe, while the risk of drought increases mainly in southern Europe. Already now[30], although a significant trend in extreme river flows has not yet been observed, twice as many river flow maxima occurred in Europe between 1981 and 2000 than between 1961 and 1980. Since 1990, 259 major river floods have been reported in Europe, of which 165 have been reported since 2000. The rise in the reported number of flood events over recent decades results mainly from better reporting and land-use changes.[31]

Increase in intense short-duration precipitation in most of Europe is likely to lead to increased risk of flash floods. On the other hand climate change is projected to increase the frequency and intensity of droughts in many regions of Europe as a result of higher temperatures, decreased summer precipitation, and more and longer dry spells. The regions most prone to an increase in drought hazard are southern and south-eastern Europe, but minimum river flows will also decrease significantly in many other parts of the continent, especially in summer.[32]

4.2.2 Coastal and marine systems

Wind-driven waves and storms are seen as the primary drivers of short-term coastal processes on many European coasts, and some climate simulations reinforce existing trends in storminess. These indicate some further increase in wind speeds and storm intensity in the north-eastern Atlantic during at least the early part of the 21st century (2010 to 2030), with a shift of storm centre maxima closer to European coasts. At the same time these simulations also suggest a decline in storminess and wind intensity eastwards into the Mediterranean, but with localised increased storminess in parts of the Adriatic, Aegean and Black Seas.

It is also expected that particularly for the Baltic and southern North Sea, fewer but more extreme surge events occur, combined with a significant increase of wave heights of >0.4m in the north-eastern Atlantic by the 2080s This combination will be particularly significant because it will cause erosion and flooding in estuaries, deltas and embayments.

Model projections of the IPCC give a global mean sea-level rise of 0.09 to 0.88 m by 2100, with sea level rising at rates circa 2 to 4 times faster than those of the present day. In Europe, regional influences may result in sea-level rise being up to 50% higher than these global estimates. Furthermore, the sustained melting of Greenland ice and other ice stores under climate warming, coupled with the impacts of a possible abrupt shut-down of the Atlantic meridional overturning circulation (MOC) after 2100, provide additional uncertainty to sea-level rise for Europe. Overall, this could have some severe impacts on Europe's coastal areas, causing flooding, land loss, the salinisation of groundwater and the destruction of built property and infrastructures. It is projected that up to an additional 1.6 million people each year in the Mediterranean, northern and western Europe, might experience coastal flooding by and approximately 20% of existing coastal wetlands may disappear by 2080.[33]

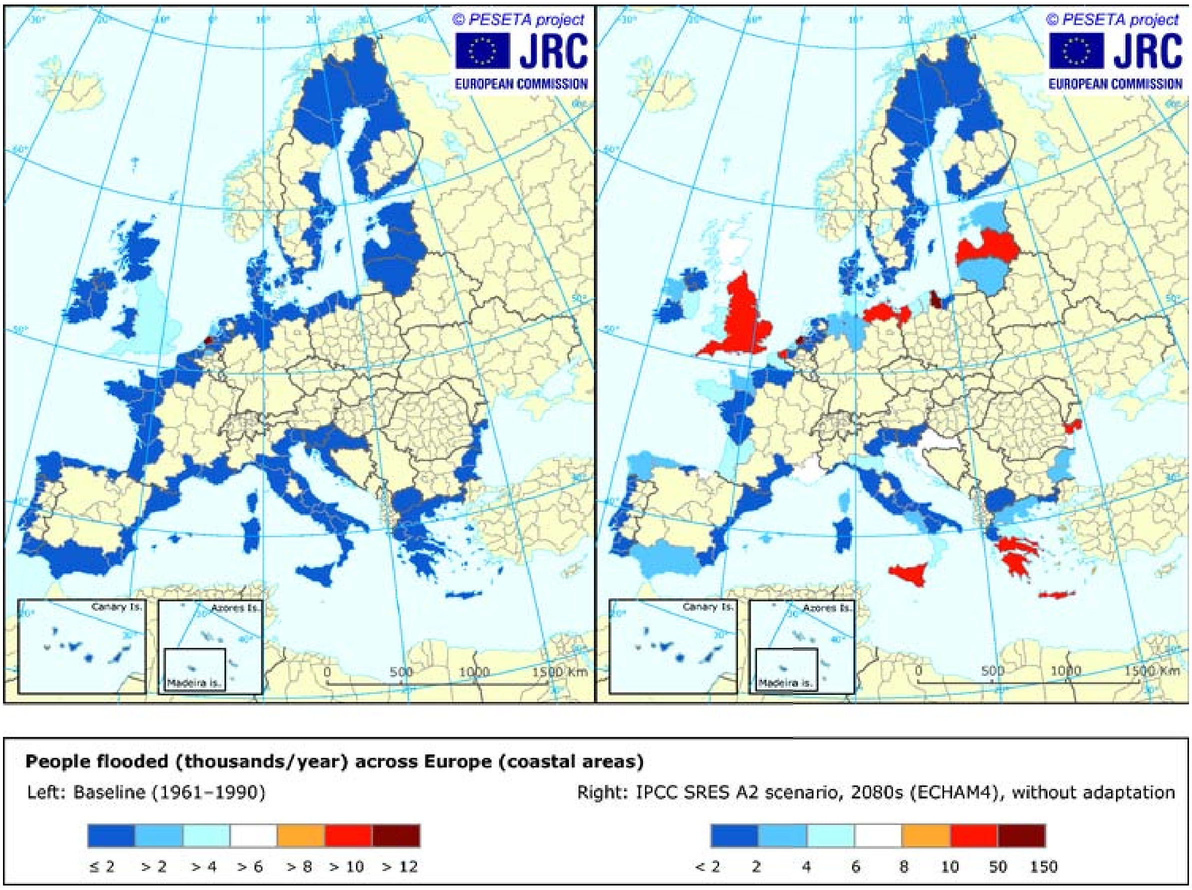
Various adaptation measures are available to reduce these risks. But there are limits to adaptation: due to the thermal inertia of the oceans, sea-level rise would not stop by 2100 even if greenhouse gas concentrations were stabilised. Over a period of centuries and millennia, a very large sea-level rise could

[29] EEA, 2008, op. cit. p. 93
[30] Alcamo, J., et. al. ,2007, op.cit. p. 550
[31] EEA, 2008, op. cit. p. 99
[32] EEA, 2008, op. cit. p. 99
[33] Alcamo, J., et. al. ,2007, op.cit. p. 551

result from the melting of the world's major ice sheets in Greenland and on the West Antarctic ice shelf, which have an SLR potential of about 7 and 5–6 m respectively, should they melt completely

Changes in the timing of seasonal biological phenomena (phenology) and distribution of marine species have been observed, including earlier seasonal cycles (by 4–6 weeks) and northward movements, by up to 1 100 km over the past 40 years, which seems to have accelerated since 2000. These changes will affect marine ecosystems, biodiversity and affect fisheries, including increasing the vulnerability of North Sea cod stocks to over-fishing and a decline in seabird populations. Sub-tropical species are occurring with increasing frequency in European waters, and sub-Arctic species are receding northwards.[34]

Figure 5: Modelled number of people flooded across Europe's coastal areas in 1961–1990 and in the 2080s



Source: EEA, Impacts of Europe's changing climate – 2008 indicator-based assessment

4.2.3 Cryosphere, mountains and sub-Arctic regions

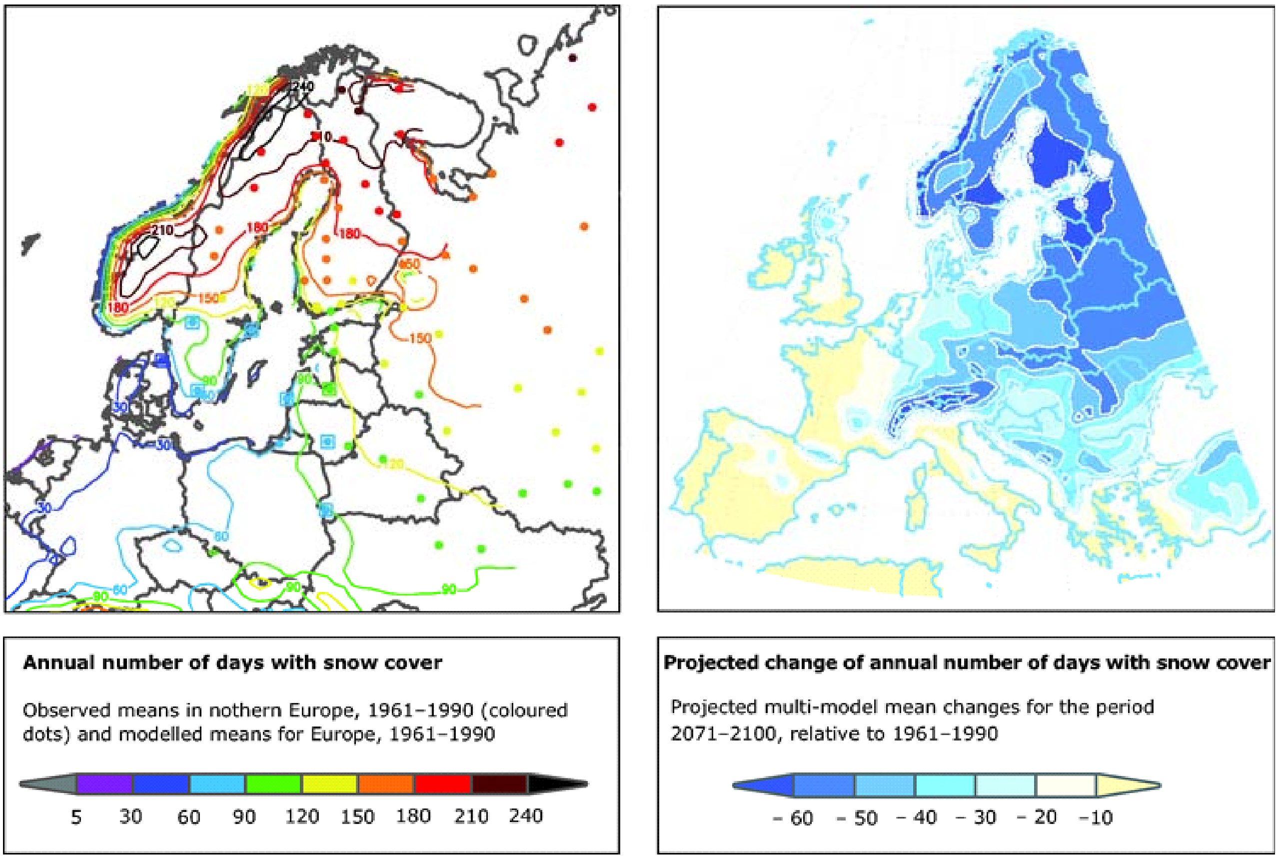
European glaciers are melting rapidly: those in the Alps have lost two thirds of their volume since 1850, with loss accelerating since the 1980s, and they are projected to continue their decline. Snow cover has decreased by 1.3 % per decade during the past 40 years, with the greatest losses in spring and summer, and decreases are projected to continue. These various changes will cause natural hazards and damage to infrastructure and changes in river flows and seasonality, thus substantially affecting the hydrological cycle in river catchment areas. The reduction in Arctic sea ice, especially in summer, has accelerated the past five decades, with a record low extent in September 2007 of about half the normal minimum in the 1950s. Arctic sea ice may even disappear at the height of the melting season in the coming decades, creating a feedback

[34] EEA, 2008, op. cit. p. 85

that will further increase climate change because dark open water reflects much less sunlight than white snow-covered surfaces. Species specialised for life in the ice are threatened. Less ice will ease access to the Arctic's resources. Oil and gas exploration, shipping, tourism and fisheries will offer new economic opportunities, but also increase risks to the Arctic environment.[35]

In the future the duration of snow cover is expected to decrease by several weeks for each °C of temperature increase in the Alps region at middle elevations and an upward shift of the glacier equilibrium line is expected from 60 to 140 m/°C. Glaciers will experience a substantial retreat during the 21st century and small glaciers will disappear, while larger glaciers will suffer a volume reduction between 30% and 70% by 2050.[36] This will have has serious consequences for river flow. It affects freshwater supply, river navigation, irrigation and power generation. It could cause natural hazards and damage to infrastructure.

Figure 6: Annual number of days with snow cover over European land areas 1961–1990 and projected change for 2071–21



Source: EEA, Impacts of Europe’s changing climate – 2008 indicator-based assessment

Rising temperatures and melting permafrost will destabilise mountain walls and increase the frequency of rock falls, threatening mountain valleys. Changes in snowpack and glacial extent may also alter the likelihood of snow and ice avalanches.

[35] EEA, 2008, op. cit. p. 12
[36] Alcamo, J., et. al. ,2007, op.cit. p. 551

It is virtually certain that European mountain flora will undergo major changes due to climate change. Overall trends are towards increased growing season, earlier phenology and shifts of species distributions towards higher elevations. Similar shifts in elevation are also documented for animal species. Local plant species losses of up to 62% are projected for Mediterranean and Lusitanian mountains by the 2080s and mountain regions may additionally experience a loss of endemism due to invasive [37]

Forests

In much of continental Europe, the majority of forests are growing faster now than in the early 20th century, due to advances in forest management practices, increased nitrogen deposition, and reduced acidification by air pollution (sulphur dioxide) and also increasing temperatures and atmospheric CO2 concentrations.[38]

Forest ecosystems in Europe are very likely to be strongly influenced by climate change and other global changes, as forest area is expected to expand in the north, but contract in the south. The distribution of a number of typical tree species is likely to decrease in the Mediterranean. In northern Europe, climate change will alter phenology and substantially increase net primary productivity and biomass of forests.

Hazards for forest are likely to increase, although expected impacts are regionally specific, e.g. fire danger, length of the fire season, and fire frequency and severity are very likely to increase in the Mediterranean. Albeit less, fire danger is likely to also increase in central, eastern and northern Europe. Additionally, the range of important forest insect pests may expand northward.[39]

4.2.4 Biodiversity

Climate change is affecting the physiology, phenology and distribution of European plant and animal species with some models indicating that more than half of the plant species could become vulnerable, endangered, critically endangered or committed to extinction by 2080. The range of plants is very likely to expand northward and contract in southern European mountains and in the Mediterranean Basin.[40] By the late 21st century, plant species are projected to have shifted several hundred kilometres to the north, forests are likely to have contracted in the south and expanded in the north, and 60 % of mountain plant species may face extinction. The rate of change will exceed the ability of many species to adapt, especially as landscape fragmentation may restrict movement.[41]

An assessment of European fauna indicated that the majority of amphibian (45% to 69%) and reptile (61% to 89%) species could expand their range. Currently, species richness in inland freshwater systems is highest in central Europe declining towards the south and north because of periodic droughts and salinisation. Increased projected runoff and lower risk of drought in the north will benefit the fauna of these systems, but increased drought in the south will have the opposite effect. Higher temperatures are likely to lead to increased species richness in freshwater ecosystems in northern Europe and decreases in parts of south-western Europe.[42]

Birds, insects, mammals and other animal groups are also moving northwards and uphill. A combination of the rate of climate change, habitat fragmentation and other obstacles will impede the movement of many animal species, possibly leading to a progressive decline in European biodiversity. Distribution changes are projected to continue. Suitable climatic conditions for Europe's breeding birds are projected to shift nearly 550 km north-eastward by the end of the century, with the average range size shrinking by 20 %. Projections

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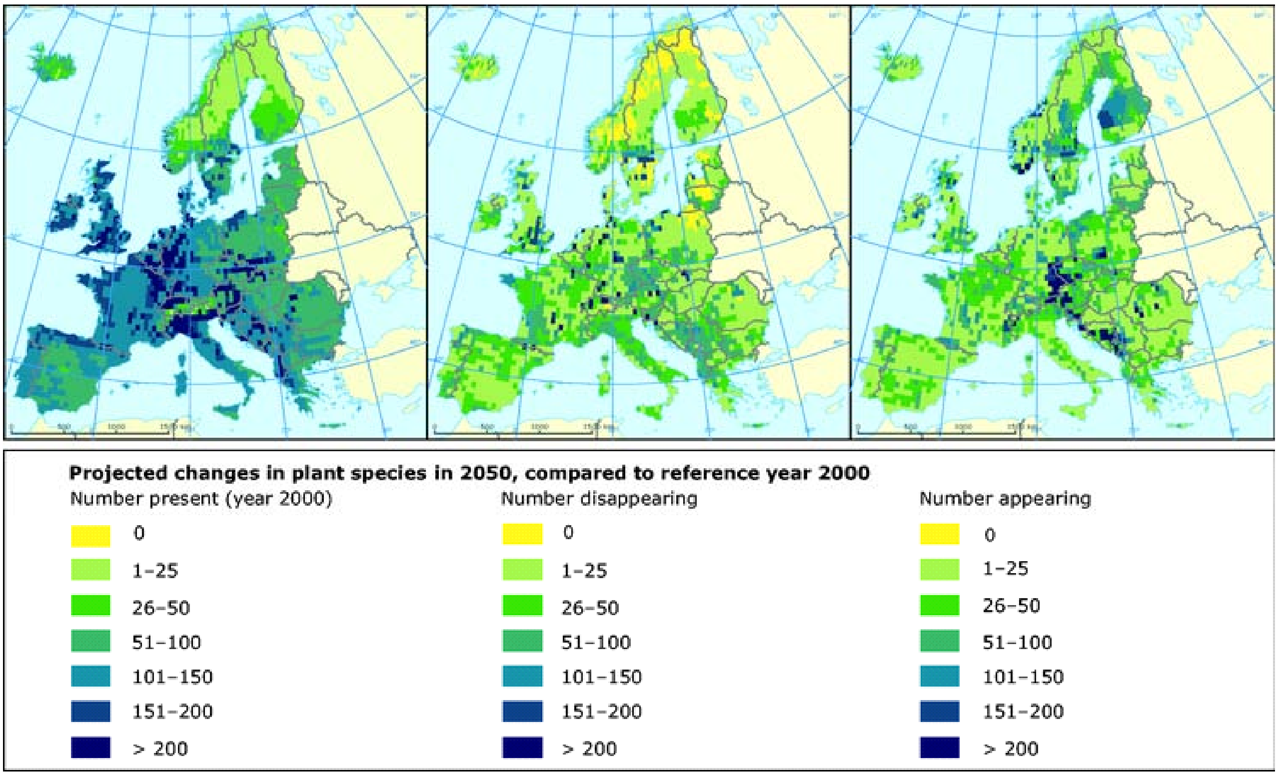
[37] Alcamo, J., et. al. ,2007, op.cit. p. 551
[38] EEA, 2008, op. cit. p. 14
[39] Alcamo, J., et. al. ,2007, op.cit. p. 552
[40] Alcamo, J., et. al. ,2007, op.cit. p. 553
[41] EEA, 2008, op. cit. p. 13
[42] Alcamo, J., et. al. ,2007, op.cit. p. 554

for 120 native European mammals suggest that, assuming no migration, up to 9 % risk extinction during the 21st century.[43]

Sea-level rise is likely to have major impacts on biodiversity. Examples include flooding of haul-out sites used for breeding nurseries and resting by seals. Increased sea temperatures may also trigger large scale disease-related mortality events of dolphins in the Mediterranean and of seals in Europe. Seals that rely on ice for breeding are also likely to suffer considerable habitat loss. Sea-level rise will reduce habitat availability for bird species that nest or forage in low-lying coastal areas. [44]

Figure 7: Projected changes in number of plant species in 2050



Source: EEA, Impacts of Europe's changing climate – 2008 indicator-based assessment

Overall, climate change has caused advancement in the life cycles of many animal groups (phenology), including frog spawning, bird nesting and the arrival of migrant birds and butterflies, and these trends are projected to continue. Populations may explode if the young are not exposed to normal predation pressures. Conversely, populations may crash if the emergence of vulnerable young is not in synchrony with their main food source or if shorter hibernation times lead to declines in body condition. [45]

4.3 Economic and social impacts and vulnerabilities

4.3.1 Agriculture and fisheries

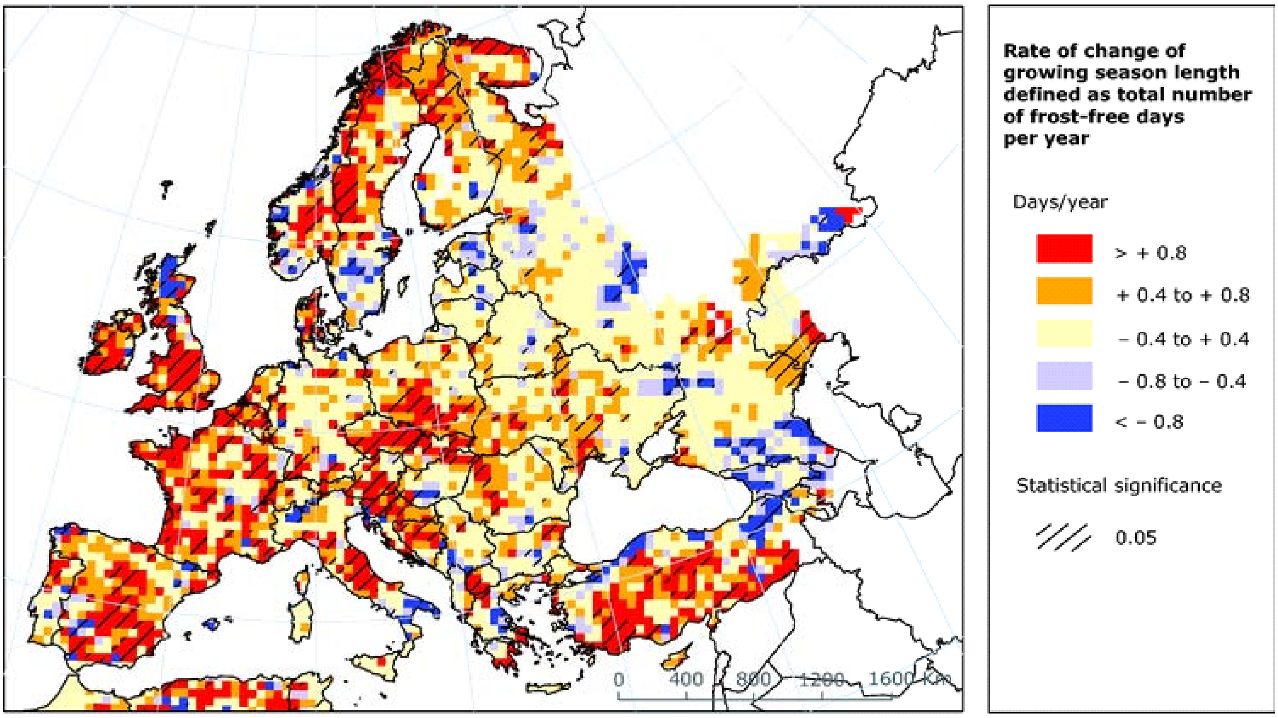
In agriculture, climate change affects the growing season and average yields while also key relevant land-use and management changes occur, making it difficult to detect climate change-induced trends. The length

[43] EEA, 2008, op. cit. p. 13
[44] Alcamo, J., et. al. ,2007, op.cit. p. 554
[45] EEA, 2008, op. cit. p. 13

of the growing season of several agricultural crops has increased at northern latitudes, favouring the introduction of new species that were not previously suitable. However, there has been a shortening of the growing season locally at southern latitudes. The flowering and maturity of several species in Europe now occurs two or three weeks earlier than in the past with consequent higher risk of frost damage from delayed spring frosts.[46]

The effects of climate change and increased atmospheric CO2 are expected to lead to overall small increases in European crop productivity. However, technological development (e.g., new crop varieties and better cropping practices) might far outweigh the effects of climate change. Combined yield increases of wheat by 2050 could range from 37% to 101% depending on the scenario. Climate-related increases in crop yields are expected mainly in northern Europe, e.g., wheat: +2 to +9% by 2020, +8 to +25% by 2050, +10 to +30% by 2080 while the largest reductions of all crops are expected in the Mediterranean, the south-west Balkans and in the south of European Russia. In southern Europe, general decreases in yield (e.g., legumes -30 to + 5%; sunflower -12 to +3%and tuber crops -14 to +7%by 2050) and increases in water demand (e.g., for maize +2 to +4% and potato +6 to +10% by 2050) are expected for spring sown crops. The impacts on autumn sown crops are more geographically variable; yield is expected to strongly decrease in most southern areas, and increase in northern or cooler areas (e.g., wheat: +3 to +4% by 2020, -8 to +22% by 2050, -15 to +32% by 2080).

Figure 8: Rate of change of crop growing season length 1975–2007



Source: EEA, Impacts of Europe's changing climate – 2008 indicator-based assessment

Some crops that currently grow mostly in southern Europe (e.g., maize, sunflower and soybeans) will become viable further north including Ireland, Scotland, southern Sweden and Finland. By 2050 energy crops, starch crops, cereals and solid biofuel crops show a northward expansion in potential cropping area, but a reduction in southern Europe. In particular, in the European Mediterranean region, increases in the

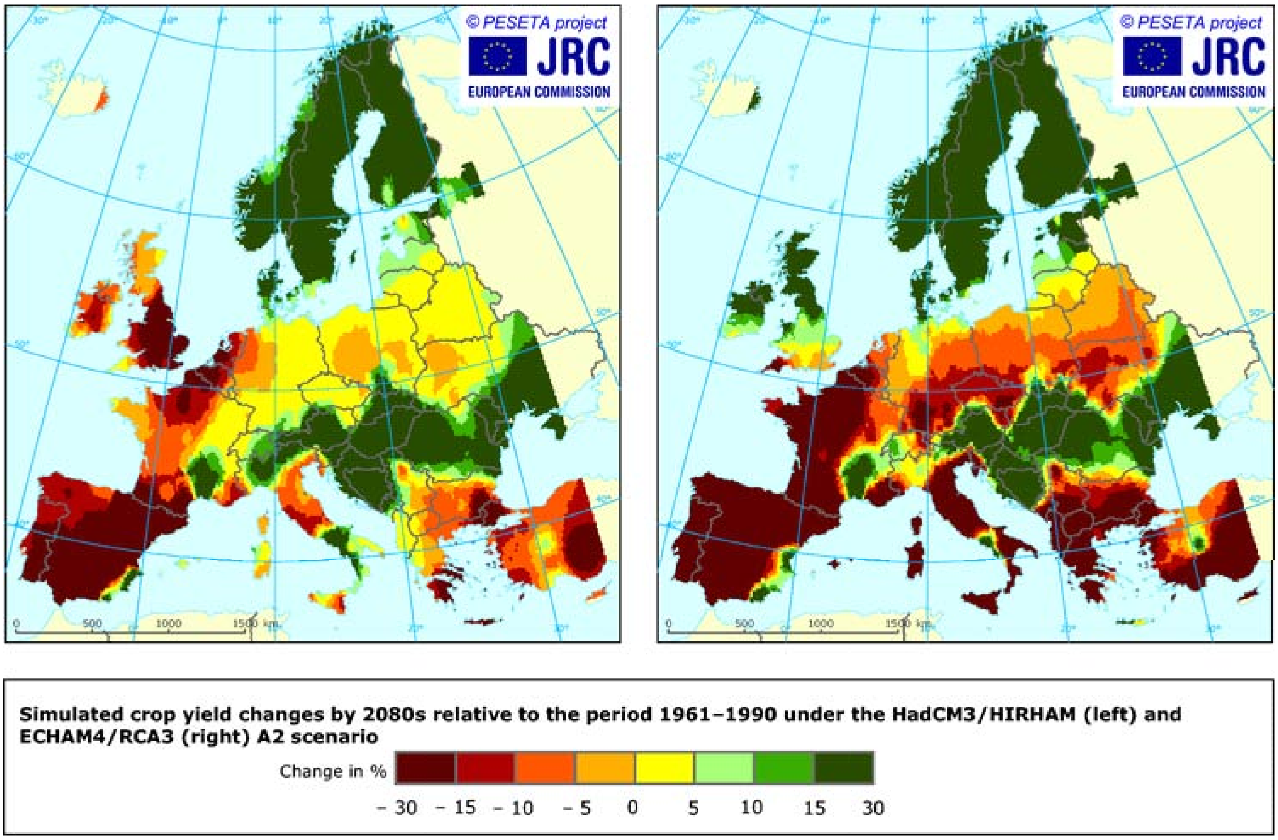
46 EEA, 2008, op. cit. p. 14

frequency of extreme climate events during specific crop development stages (e.g., heat stress during flowering period, rainy days during sowing time), together with higher rainfall intensity and longer dry spells, are likely to reduce the yield of summer crops.

Climate change will modify other processes on agricultural land. An increase in the frequency of severe heat stress in Britain is expected to enhance the risk of mortality of pigs and broiler chickens grown in intensive livestock systems. Increasing temperatures may also increase the risk of livestock diseases by supporting the dispersal of insects, enhancing the survival of viruses from one year to the next and improving conditions for new insect vectors that are now limited by colder temperatures.

Temperature increase has a major effect on fisheries production in the North Atlantic, causing changes in species distribution, increased recruitment and production in northern waters and a marked decrease at the southern edge of current ranges.[47]

Figure 9: Projected crop yield changes between the 2080s and the reference period 1961–1990 by two different models



Source: EEA, Impacts of Europe's changing climate – 2008 indicator-based assessment

4.3.2 Energy

Under future climate change, demand for heating decreases and demand for cooling increases relative to 1961 to 1990 levels. In the UK and Russia, a 2°C warming by 2050 is estimated to decrease space heating needs in winter, thus decreasing fossil fuel demand by 5 to 10% and electricity demand by 1 to 3%. Wintertime heating demand in Hungary and Romania is expected to decrease by 6 to 8% and by 10% in Finland by the period 2021 to 2050. Around the Mediterranean, two to three fewer weeks a year will require

[47] Alcamo, J., et. al. ,2007, op.cit. p. 554 ff.

heating but an additional two to three (along the coast) to five weeks (inland areas) will need cooling by 2050, which will lead to an up to 10% decrease in energy heating requirements and up to 28% increase in cooling requirements in 2030 for the south-east Mediterranean region. A strong increase reported in cooling requirements is reported for central and southern Europe (reaching 114% for Madrid) by 2071 to 2100. Summer space cooling needs for air conditioning will particularly affect electricity demand with increases of up to 50% in Italy and Spain by the 2080s.

By the 2070s, hydropower potential for the whole of Europe is expected to decline by 6%, translated into a 20 to 50% decrease around the Mediterranean, a 15 to 30% increase in northern and eastern Europe and a stable hydropower pattern for western and central Europe There will be a small increase in the annual wind energy resource over Atlantic and northern Europe, with more substantial increases during the winter season by 2071 to 2100. By the 22nd century, 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. Climate change could have a negative impact on thermal power production since the availability of cooling water may be reduced at some locations because of climate-related decreases or seasonal shifts in river runoff.[48]

4.3.3 Transport

Higher temperatures can damage rail and road surfaces and affect passenger comfort. The likely increase in extreme weather events may cause flooding, particularly of underground rail systems and roads with inadequate drainage. High winds may affect the safety of air, sea and land transport whereas intense rainfall can also impact adversely on road safety although in some areas this may be offset to a degree by fewer snowy days. Reduced incidences of frost and snow will also reduce maintenance and treatment costs. Droughts and the associated reduced runoff may affect river navigation on major thoroughfares such as the Rhine and shrinkage and subsidence may damage infrastructure. Reduced sea ice and thawing ground in the Arctic will increase marine access and navigable periods for the Northern Sea Route.[49]

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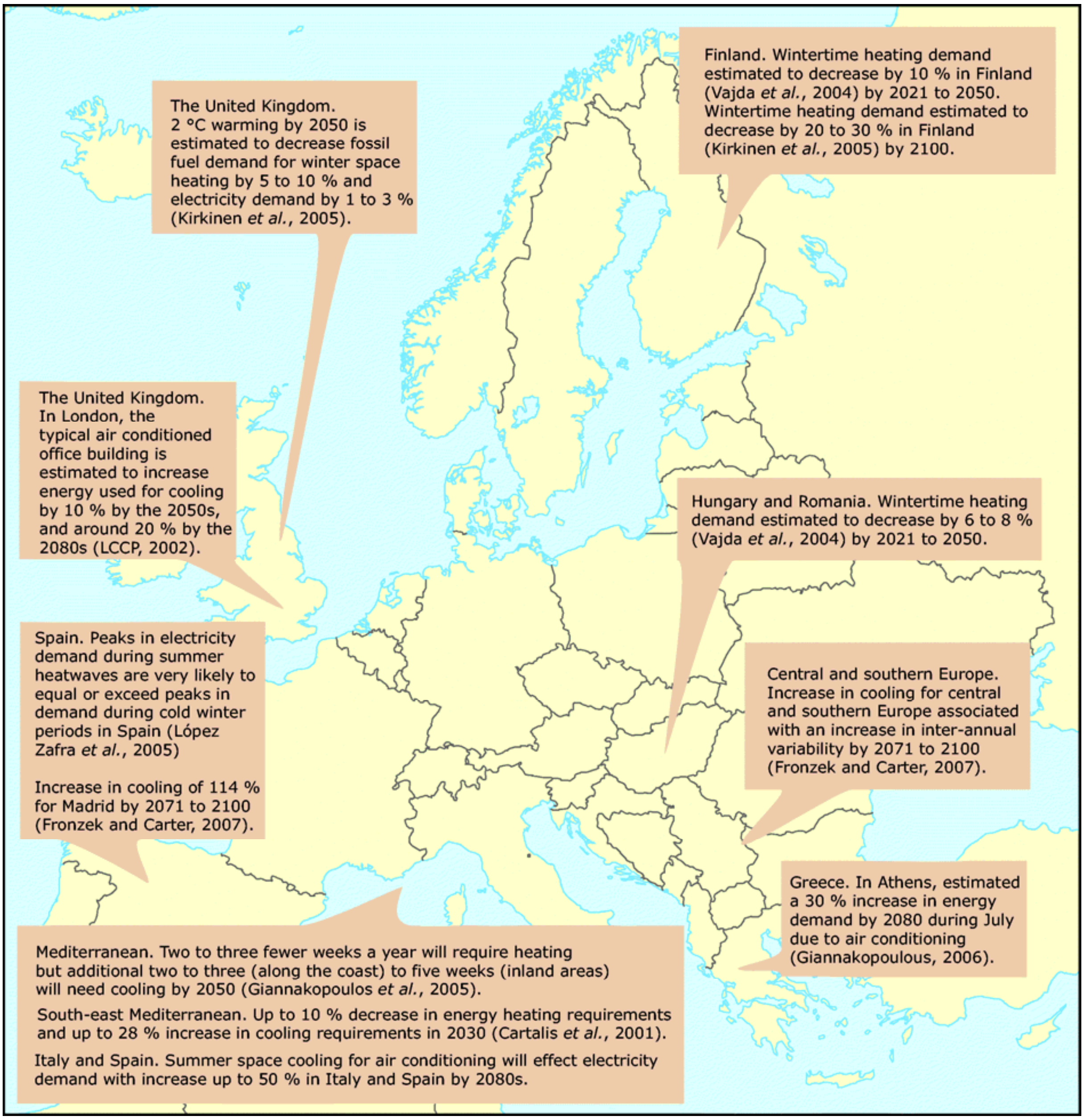
[48] Alcamo, J., et. al. ,2007, op.cit. p. 556
[49] Alcamo, J., et. al. ,2007, op.cit. p. 556

Figure 10: Projections of energy demand for several time horizons in Europe



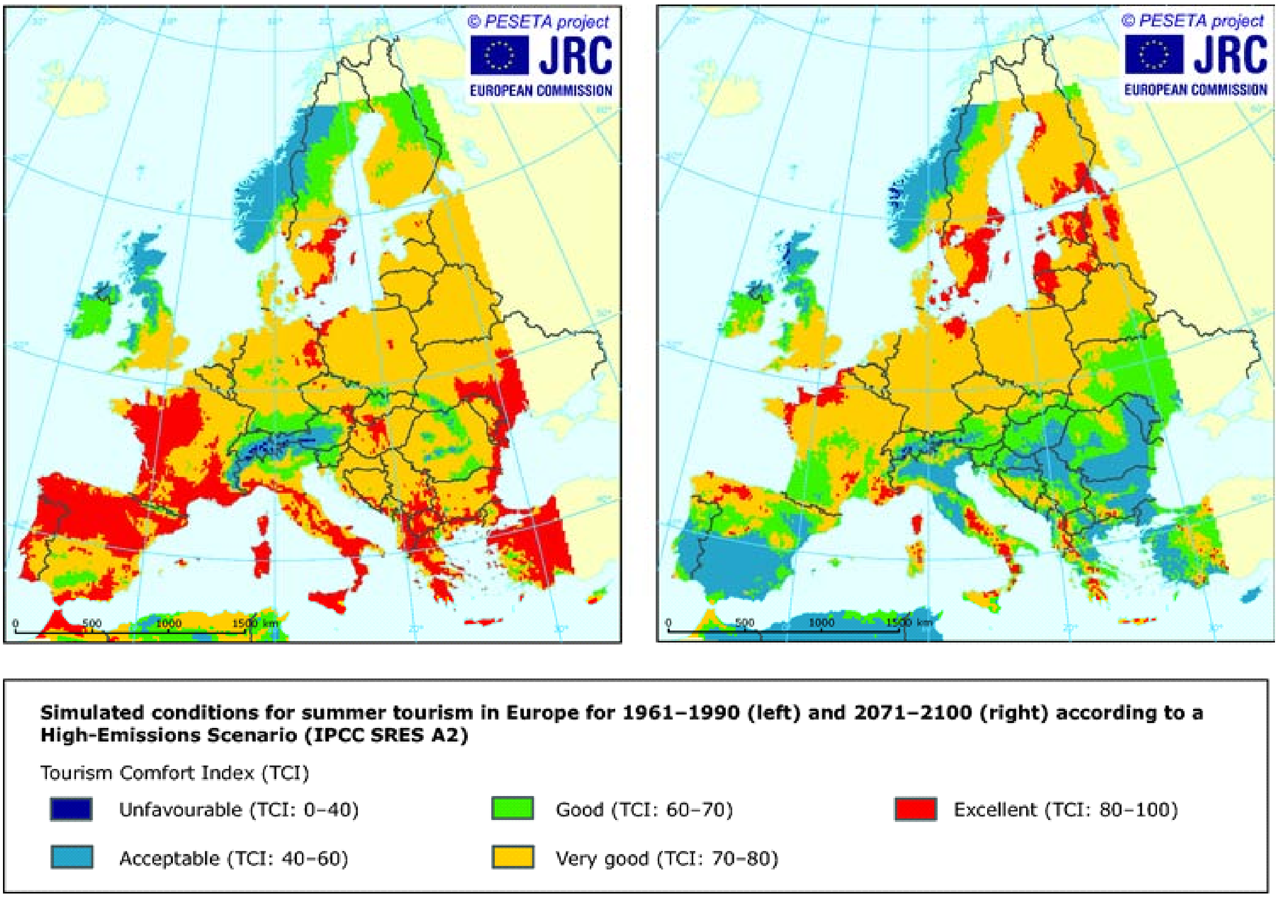
Source: Energy and environment report 2008

4.3.4 Tourism and recreation

Conditions for tourism are expected to improve in northern and western Europe. Mountainous parts of France, Italy and Spain could become more popular because of their relative coolness. Higher summer temperatures may lead to a gradual decrease in summer tourism in the Mediterranean but an increase in spring and perhaps autumn and it is shown that Greece and Spain will experience a lengthening and a flattening of their tourism season by 2030. Occupancy rates associated with a longer tourism season in the Mediterranean will spread demand evenly and thus alleviate the pressure on summer water supply and energy demand.

The ski industry in central Europe is likely to be disrupted by significant reductions in natural snow cover especially at the beginning and end of the ski season, e.g. for the Austrian Alps it is shown that (with no snowmaking adaptation considered), a 1°C rise leads to four fewer weeks of skiing days in winter and six fewer weeks in spring.[50]

Figure 11: Modelled conditions for summer tourism in Europe for 1961–1990 and 2071–2100



Source: EEA, Impacts of Europe's changing climate – 2008 indicator-based assessment

4.3.5 Human health

Over the next century, heat-waves are very likely to become more common and severe causing more heat-related deaths, even after assuming acclimatisation. Cold mortality is a problem in mid-latitudes but is likely to decline with milder winters.

Climate change is likely to increase the risk of mortality and injury from wind storms, flash floods and coastal flooding. Moreover, a number of vector-borne diseases are expected to increase in the near future. The tiger mosquito, a transmitter of a number of viruses, has extended its range in Europe substantially over the past 15 years and is projected to extend even further. Ticks and the associated Lyme disease and tick-borne encephalitis are moving into higher altitudes and latitudes. There is a risk of additional outbreaks of Chikungunya (a virus that is highly infective and disabling but not transmissible between people) and a potential for localised dengue to re-appear. Changes in the geographic distribution of the sandfly vector are occurring in several European countries and there is a risk of human Leishmania cases further north. The possible spread of these diseases is very dependent on early detection and the preventive measures in place. Some water- and food-borne disease outbreaks are expected to become more frequent with rising

[50] Alcamo, J., et. al. ,2007, op.cit. p. 556 ff.

temperatures and more frequent extreme events. The risk is very dependent on human behaviour and the quality of health care services and their ability to detect early and act.[51]

Climate change is also likely to affect water quality and quantity in Europe, and hence the risk of contamination of public and private water supplies. Both extreme rainfall and droughts can increase the total microbial loads in freshwater and have implications for disease outbreaks.

Climate change may increase summer episodes of photochemical smog due to increased temperatures, and decreased episodes of poor air quality associated with winter stagnation. Stratospheric ozone depletion and warmer summers influence human exposure to ultra-violet radiation and therefore increase the risk of skin cancer. Pollen phenology is changing in response to observed climate change, especially in central Europe, and at a wide range of elevations. Earlier onset and extension of the allergenic pollen seasons are likely to affect some allergenic diseases.[52]

4.3.6 Urban regions and infrastructure

The urban heat island effect means that urban areas can experience higher temperatures than more rural counterparts, making overheating more pronounced in cities, which is intensified further by reducing green zones in cities. To illustrate In the UK, for a global temperature rise of 3°C, temperatures in London could be up to 7°C warmer than today because of the combined effect of climate change and the urban heat island effect, meaning that comfort levels will be exceeded for people at work for one-quarter of the time on average in the summer. [53] This can have several effects, including an increase in the number of excess deaths, particularly of vulnerable people, a reduction in the comfort of urban residents, and an increased demand for air conditioners, thus increasing energy requirement and further exacerbating climate change.

4.3.7 Other Economic impacts

Economic costs and potential benefits of climate impacts have been quantified, but factors other than climate change often have a dominant effect, making assessments uncertain. Furthermore the costs of adaptation actions are poorly understood for both the current situation and the future. However, about 90 % of all natural disasters that occurred in Europe since 1980 are directly or indirectly attributable to weather and climate, representing about 95 % of the economic losses caused by catastrophic events. Overall losses resulting from weather- and climate-related events have clearly increased during the past 25 years. Even though social change and economic development are the main factors responsible for this increase, there is evidence that changing patterns of weather disasters are also drivers. However, it is still not possible to determine the proportion of the increase in damage that might be attributed to anthropogenic climate change.

§ Economic losses as a consequence of extreme flood events in recent years have been dramatic. Flood disasters increased significantly in Europe during the 1990s and the 2000s. The estimated losses in central Europe in 2002 were EUR 17.4 billion.

§ Coastal flooding can lead to important losses. By 2100, the population in the main coastal European cities exposed to sea-level rise and associated impacts on coastal systems is expected to be about 4 million and the exposed assets more than EUR 2 trillion (without adaptation).

§ Economic consequences of climate change impacts will be particularly pronounced in areas where increases in water stress are projected.

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[51] EEA, 2008, op. cit. p. 15
[52] Alcamo, J., et. al. ,2007, op.cit. p. 557
[53] Stern Review Report, p. 12

- The hot summer of 2003 in Europe is estimated to have led to EUR 10 billion in economic losses to farming, livestock and forestry from the combined effects of drought, heat stress and fire.
- Climate-related increases in crop yields are expected mainly in northern Europe (by about 10 %) with reductions (of 10 % or more) in the Mediterranean and the south-west Balkans.
- The cumulative welfare losses due to loss of ecosystem services could be equivalent to 7 % of annual consumption by 2050.
- Future projections of climate change suggest reductions in heating degree days in Europe, but increases in cooling degree days. The net change in energy demand is difficult to predict, but there will be strong distributional patterns, with significantly reduced space-heating demand in northern Europe and increased space-cooling demand in southern Europe.
- The projected change in river runoff due to climate change will result in an increase in hydropower production by about 5 % and more in northern Europe and a decrease by about 25 % or more in the south.
- Climate change could have an adverse impact on thermal power production as most studies show that summer droughts will be more severe, hence limiting the availability of cooling water in terms of quantity, appropriate temperature and power plant efficiency.
- Changes in climate are starting to impact upon the attractiveness of many of the Mediterranean's major resorts, while improving it in other regions.[54]

4.4 Global spillovers on Europe

4.4.1 General Risks

At higher temperatures, Europe and other developed economies face a growing risk of large-scale shocks. Thus extreme weather events could affect trade and global financial markets through disruptions to communications and more volatile costs of insurance and capital. Likewise major areas of the world could be devastated by the social and economic consequences of very high temperatures. As history shows, this could lead to large-scale and disruptive population movement and trigger regional conflict. Thus, it might be the case that climate change increases migratory pressures on developed countries significantly.

Additionally the EU and other developed countries may become drawn into climate-induced conflicts in regions that are hardest hit by the impacts, particularly as the world becomes increasingly interconnected. Direct conflict between nation states because of water scarcity has been rare in the past, but can increase in the future.

4.4.2 Europe's neighbours

Mediterranean countries

Giannakopoulos et.al.[55] analyse the impacts of a 2°C global temperature rise on the Mediterranean region for the thirty-year period 2031-2060. Their results show that a global temperature rise of 2°C is likely to lead to a corresponding warming of 1-3 °C in the Mediterranean region. The warming is likely to be higher inland than along the coast. The largest increase in temperature is expected to take place in the summer, when extremely hot days and heatwaves are expected to increase substantially, especially in inland and southern

[54] EEA, 2008, op. cit. p. 15
[55] Giannakopoulos, C., Bindi, M., LeSager, P. and Tin, T., (2005) Climate change impacts in the Mediterranean resulting from a 2°C global temperature rise. A report for the WWF 1July 2005.

Mediterranean locations. The change in precipitation is more difficult to predict, as either a general drop in precipitation but also rainfall increases in the northern Mediterranean, particularly in winter are likely, depending on the climate scenario used. Yet in all their scenarios precipitation decreases substantially in the summer in both the north and the south. Longer droughts will be become more common, and are the number of dry days increases while the number of wet and very wet days remains unchanged. This can imply that when it rains it will rain more intensely and strongly, especially at certain locations in the northern Mediterranean. The climate change impacts on the Mediterranean is summarised in Table 3.

The impacts of the climatic changes are far reaching.

Thus, fire risk is likely to increase nearly everywhere in the Mediterranean region, especially in inland locations. The southern Mediterranean is at risk of forest fire all year round. In the Iberian Peninsula, northern Italy and over the Balkans, the period of extreme fire risk lengthens substantially. The only region that shows little change in fire risk is in the South-Eastern Mediterranean.

Agricultural crop yields are expected to decline throughout the region. The southern Mediterranean is likely to experience an overall reduction of crop yields due to the change in climate. In some locations in the northern Mediterranean, the effects of climate change and its associated increase in carbon dioxide may have little or small positive impacts on yields, provided that additional water demands can be met. The adoption of specific crop management options may help in reducing the negative responses of agricultural crops to climate change. However, such options could require up to 40% more water for irrigation, which may or may not be available in the future.[56]

Heating degree days decrease substantially in the northern Mediterranean and cooling degree days increases everywhere in the Mediterranean, especially in the south. This change can potentially shift the peak in energy demand to the summer season with implications for the need for addtional energy capacity and increased stress on water resources.[57]

Increases in temperature are expected to lead to a reduction of tourist arrivals as warmer northern European summers would encourage northern Europeans to take domestic holidays, while simultaneously more frequent and intense heat waves and drought are likely to discourage holidays in the Mediterranean in the summer. Furthermore it is likely that the Mediterranean holiday season may shift to spring and autumn.

Furthermore, global warming and its associated reduction in precipitation are expected to reduce surface runoff and water yields in the Mediterranean region. In some countries, this could result in water demand exceeding available water supply. In terms of biodiversity, climate change is likely to lead to shifts in the distributions and abundances of species, potentially increasing the risks of extinction. In addition, forest fires are expected to encourage the spread of invasive species which in turn, have been shown to fuel more frequent and more intense forest fires.[58]

Looking at **North Africa** in more detail, the main vulnerabilities with respect to climate change are all in one way or another related to water, i.e. the coastline, agriculture and water supply.

As far as the coastline is concerned a rise of sea level could have enormous social and economic impacts on the North African countries. To illustrate, in Tunisia, the coastline is the hub of the country with around sixty per cent of the population living there, 70 per cent of all economic activity taking place in the region, and 90 per cent of its tourist attractions occurring there.

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[56] Giannakopoulos, C. et al. (2005), op. cit. p.D
[57] Giannakopoulos, C. et al. (2005), ibdm.
[58] Giannakopoulos, C. et al. (2005), op. cit. p.E

Table3: Summary table of climate changes in the Mediterranean countries

	High Temperatures					Low Temperatures			Precipitation				
	Summer days	Hot days	Tropical nights	Days > 90^{th} quantile	Nights > 90^{th} quantile	Frost nights	Ice days	[1]Days < 10^{th} quantile	Relative precip.var.	Dry days	Rainfall between 1-10mm	Max 3-days rainfall	Longest dry spell
NW Iberian Peninsula	1	1		1	1	-1		-2		2	-2	3	
South of France (inland)	3	1	1	2	2	-1		-2	-1	3	-2	3	
Coast of S. of France	1		2	2	2	-1		-2	-1	2	-2	3	1
Corsica	1	1	2	2	2	-1		-2	-1	2	-1	2	1
Sardinia	1		3	2	2			-3		2	-1	1	2
Sicily / South Italy	3		3	3	2 3			-3		3	-1	3	3
North Adriatic	3	3		2	2	-2	-1	-2	-1	3	-2	1 2	1
Central Balkans	3	3		2	2	-2	-1	-2		3	-3		
Central Greece	2	1	2	2	2	-1		-2	-1	2	-2	1	1
Peloponnese	3		3	2	2			-3	-1	2	-1	2	2
Crete	3		3	3	3			-3	-1	2	-1		1
Coastal Turkey	1 2	1	1 2	2	2	-1		-2	-1	2	-1	-1 2	1
Turkey Inland	3	3		2	2 3	-2	-1	-2		3	-2		2
Cyprus	1		3	1	1			-3	-1	1	1		-1
Lebanon-Israel-Nile Delta	1	1	3	3	3	-1		-3	[2]	1	-1		
E. Egypt-E. Libya	3	1	3	2	3			-3	-3		-1		-1
W. Libya	3	1	3	2	3			-3	-3		-1		3
E. Maghreb	2	3	3	2	2	-2		-2	-3	2	-2		
W. Maghreb	3	3	3	2	2	-2		-2		2	-2	-1	3
South Iberian Peninsula	2	2	2	2	2	-1		-2	-1	2	-2		3
Central Spain	3	3	1	2	2	-2		-2	-1	3	-2	-1	1

Synoptic Table. Red = Large change=3, Yellow = Moderate change=2, Grey = Small change=1, White = No change, (-)=decrease. Notes: [1] very similar results for nights; [2] depend on scenario. Typical temporal values: Big is about 1 month or more; Moderate is about 2-3 weeks; Small is about 1 week (few days).

Source: Giannakopoulos, C., Bindi, M., LeSager, P. and Tin, T., (2005) Climate change impacts in the Mediterranean resulting from a 2°C global temperature rise. A report for the WWF 1July 2005, p.35

Overall the main vulnerabilities with respect to the coastline are the erosion of some coastlines, loss of land to sea water, intrusion of sea water onto land and salification of coastal ground water, changes in agricultural and aquatic production along the coastline and socio-economic endangerment of these coastal zones.[59]

With respect to agriculture climate change is expected to have equally serious consequences. Thus global warming and changes in precipitation might lead to a greater erosion, leading to widespread soil degradation, a reduction of deficient yields from rain-based agriculture of up to 50 per cent during the 2000–2020 period, a reduced crop growth period a reduced agricultural activity in coastal zones due to anticipated salinization of ground water, a reduced agricultural production linked to higher water demand in this sector, while water supply decreases at the same time.[60]

With respect to the water sector, the analysis conducted in North Africa revealed the following risks: a probable decrease in water flow, a change in seasonal water recharging, an increased evapotranspiration and, consequently, water salinity, a drop in water tables and increased salinity of coastal ground water; and a warmer, less aerated surface water, with less flow and therefore less able to dilute and biodegrade certain pollutants.[61]

Europe and Central Asia (ECA)

A recent study by the World Bank[62], made available by the Regional Future Initiative network, analyses in detail the effects of climate change on the ECA region[63] that covers a wide range of EU neighbour countries (as well as some EU member states). In summary the results are:

Temperatures are projected to continue increasing everywhere in the region, with the greater changes occurring in the more northern latitudes. The north is projected to see greater temperature changes in winter, with the number of frost days declining by 14 to 30 days over the next 20 to 40 years. Southern parts of the region are expected to see the greatest changes in the summer, with the number of hot days increasing by 22 to 37 days over the same period.

Water availability is projected to decrease everywhere but Russia, as increased precipitation in many regions (except South-eastern Europe) is offset by greater evaporation due to higher temperatures. The most dramatic decreases are likely to occur in South-eastern Europe (–25%). Nevertheless, floods are expected to become increasingly common and severe as precipitation intensity will increase across the region—notably through more frequent storms and potentially through the melting of glaciers. And while in the short term, basins reliant on glacial melt for summer water may see increased water flow from melting glaciers, the long term implications for summer water availability are worrisome—particularly in irrigation-dependent Central Asia.[64]

Sea level rise will affect ECA's four basins (the Baltic Sea, the East Adriatic and Mediterranean coast of Turkey, the Black Sea and the Caspian) and the Russian Arctic Ocean. Sea level rise has been highest in the Black Sea, where it is threatening the numerous ports and towns along the Russian, Ukrainian and Georgian coasts. In the Caspian Sea, water levels are projected to drop by approximately 6 meters by the end of the 21st century, due to increased surface evaporation. This will imperil fish stock and affect coastal infrastructure.[65]

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[59] Agoumi, A., op. cit. p.5.
[60] Agoumi, A., op. cit. p.5 ff.
[61] Agoumi, A., op. cit. p.6 ff.
[62] World Bank, 2009, Managing Uncertainty: Adapting to Climate Change in ECA Countries, March 10th 2009; not published
[63] Countries covered: Albania, Armenia, Azerbaijan, Belarus, Bosnia and Herzegovina, Bulgaria, Croatia, Czech Rep., Estonia, FYR Macedonia, Georgia, Hungary, Kazakhstan, Kosovo, Kyrgyzstan, Latvia, Lithuania, Moldova, Montenegro, Poland, Romania, Russia, Serbia, Slovakia, Slovenia, Tajikistan, Turkey, Turkmenistan, Ukraine and Uzbekistan
[64] World Bank, 2009, op.cit. p. xii
[65] World Bank, 2009, op.cit. p. xiii

Extreme events combined with earlier snowmelt and hot, dry summers have caused substantial tree loss and degradation. In Russia, 20 million hectares were lost to fire in 2003 alone. The warming climate is also allowing the northward migration of pests and harmful plant species. For agriculture, net losses are likely for South-eastern Europe and Turkey, the North and South Caucasus and Central Asia. The projected impacts are mixed or uncertain in Central and Eastern Europe, Kazakhstan and the Central and Volga region of Russia.

Warmer weather and other factors associated with climate change are also having some health impacts. Malaria, which had been eradicated from Europe, is making a come-back as are a number of once rare infectious diseases; meanwhile allergies related to pollen are projected to increase, particularly in Central Europe. Hundreds of deaths were attributed to the 2001 heatwaves in Moscow.

ECA's natural resilience is weak due to decades of environmental mismanagement. Under the Soviet system economic growth was pursued in blatant disregard to natural conditions. The environmental legacy of central planning is particularly dramatic for agriculture, and greatly increases the sector's vulnerability to climate change. Uzbekistan is not the only country to have specialized in producing a small number of crops ill-suited to the local environment—other countries and sub-national regions have as well. Poor management of soil erosion and fertility, water resources, pest control, and nutrient conservation are some of the weaknesses of the agriculture system that makes it particularly vulnerable.[66]

Non-climatic factors, such as legacy issues and continued unsustainable demand will be the main driver of water stress in Europe and Central Asia over the next couple of decades. Similarly, there is much evidence that floods are usually associated with poor land use and river basin management and cannot simply be explained by increased precipitation. Overall climate-related changes to freshwater systems have been small compared to factors such as pollution, inappropriate regulation of river flows, wetland drainage, reduction in stream flow and lowering of the groundwater table (mostly due to irrigation). This suggests the urgent need to move towards more sustainable practices over the next decade before global warming's impacts become more severe.[67]

A poor quality housing stock will increase the human toll of climate change as heatwaves turn poorly ventilated buildings into furnaces and heavy rains brings leaks and mold.

In most of ECA, the power sector is hard pressed to respond to the peaks in electricity demand associated with rising summer temperatures and is badly in need of upgrade and expansion. Warmer summers, with periods of intense heat have strained the transmission networks of Turkey, Azerbaijan and Kazakhstan, as well as systems throughout South-eastern Europe. In addition extreme weather threatens the ability of networks to function as intended—especially aging and poorly maintained facilities.

ECA's transport infrastructure, with poorly maintained roads and structures, is particularly vulnerable to the stresses of climate change. More intense precipitation will make pavement subgrade less stable and weaken retaining walls. Long periods of droughts can lead to settling effects of the earth beneath the structures. More extreme temperatures will contribute to road deterioration as has already happened in Central Asia.[68]

Russia

Looking at **Russia** in more detail, given its enormous size the impacts of climate change are highly differentiated across the country. Just like in Europe the impacts of global warming tend to follow a South-North pattern, although unlike Europe Russia, because of its geographical location is expected to be a net beneficiary of climate change. Thus, if temperature increases by a 2 or 3°C above pre-industrial levels it is

[66] World Bank, 2009, ibdm.
[67] World Bank, 2009, op.cit. p. xiv
[68] World Bank, 2009, op.cit. p. xv

expected that this could bring benefits through higher agricultural yields, lower winter human mortality because more people are saved from cold-related death in the winter than succumb to heat-related death in the summer, lower heating requirements, and a potential boost to tourism. But these regions will also experience the most rapid rates of warming with serious consequences for biodiversity and local livelihoods.[69]

In the following some of the main impacts of climate change are illustrated in bit more detail:

As far as the **ecosystem** is concerned predictions are that the fertile black earth regions of Southern Russia could suffer from increased drought. Negative consequences are also expected for the tundra, which will gradually shrink (with dramatic effects on migratory birds and the connected food chain) as well as for the forested tundra, where thawing permafrost has dramatically increased deformations of buildings and infrastructure. The Northern taiga will also be heavily affected. Given that the temperature increases rapidly, ecosystems (forests) will not have time to adapt to the changes. Apart from ecological consequences this will also have economic effects as timber withdrawal will be made difficult. The Russian steppes and (semi-) deserts might be hit be increased occurrence of droughts, reducing their agricultural capacity. Only in the Middle taiga agricultural activity will probably improve.[70]

With respect to the **economic** impacts it is expected that global warming will likely to bring more positive rather than negative effects for Russia's food security and agriculture since there will be less frost vulnerable and risk-prone agricultural lands. Overall, housing, building and engineering construction, pipelines and their maintenance, as well as mining industries will require less heating and frost resisting equipment and therefore will become less energy-consuming. Tourism in Russia could increase by 30% (with only 1°C of warming) and Russia is also to experience increases in water availability. Moreover, in the Arctic global warming could also open new opportunities for oil exploration and transportation.[71]

As far as **human health** is concerned the situation is expected to improve as the area of living areas will increase and with that positive changes in working conditions and labour capacity in northern areas come along. Furthermore food security will increase. By contrast, there are also a number of negative impacts related to the quality of water supply and the spread of "insect infections", which are likely to expand given that a higher amount of more precipitation and wetland areas would expand wetlands and as a consequence increase the number of mosquitoes (malaria). [72]

4.4.3 Financial Markets

It cannot be excluded that abrupt shifts in climate and rising costs of extreme weather events will affect global financial markets. There are various risks associated with this:

§ Physical risks. The world's major financial centres (London, New York and Tokyo) are all located in coastal areas. The insurance industry estimates that in London alone at least $220 billion (£125 billion) of assets lie in the floodplain.

§ Correlated risks. At higher temperatures, climate change is likely to have severe impacts on many parts of the economy simultaneously. The shock may well exceed the capacity of markets and could potentially destabilise regions.

§ Capital constraints on insurance. Increasing costs of extreme weather will not only raise insurance premiums - they will also increase the amount of capital that insurance companies have to hold to cover

[69] Perelet, R., Pegov, S., Yulkin, M., 2007, Climate Change. Russia Country Paper, UNDP, Human Development Report 2007/2008, p.12
[70] Perelet, R., Pegov, S., Yulkin, M., op. cit. p.13ff.
[71] Perelet, R., Pegov, S., Yulkin, M., op. cit. p.18ff.
[72] Perelet, R., Pegov, S., Yulkin, M., op. cit. p.19ff.

extreme losses. If the insurance industry looks to access additional capital from the securities and bond markets, investors are likely to demand higher rates of return for placing more capital at risk, causing a rise in the cost of capital.

§ Spillover risks to other financial sectors. Failure to raise sufficient capital could mean restrictions in insurance coverage. In future, if rising weather risks cause insurance to become even less available in high-risk areas like the coast, this could be severely disruptive for other parts of the economy. Banks, for example, would be unable to offer finance where insurance is required as part of the collateral package for mortgages or loans. Lack of insurance could be particularly damaging for small and medium enterprises that will find it harder to access capital to protect against extreme events[73]

4.5 A note on adaption

Adaptation refers to policies, practices and projects which can either moderate damage and/or realise opportunities associated with climate change.[74] Thus, even in the case climate change cannot be avoided, or at least some degree stopped at a certain level (given the EU's goal to limit global warming to 2°C), negative effects of climate change can be reduced by appropriate adaptation practices.

The number of potential actions to adapt to the negative consequences are manifold, and for most individual challenges within the climate change sphere the IPCC 4th Assessment report suggests that current practices might be well suited to prevent or moderate the negative effects from these challenges.

To illustrate, the IPCC highlights the following points (with respect to chosen vulnerabilities)[75][76]:

§ Water resources

- Flood protection: reservoirs and dykes; expanded floodplain areas, emergency flood reservoirs, preserved areas for flood water, and flood warning systems, especially for flash floods.
- Water stress: impounding rivers to form in-stream reservoirs (constrained environmental regulations and high investment costs); wastewater reuse and desalination; household, industrial and agricultural water conservation, the reduction of leaky municipal and irrigation water systems, water pricing.

§ Mountains regions: Amongst the limited options to adapt are changes in infrastructure planning and building techniques. As far as the alpine vegetation is concerned, it may be possible to preserve many alpine species in managed gardens

§ Forests: changing the species composition, planting forests with genetically improved seedlings, extending the rotation period of commercially important tree species, adaptive forest management. However these adaptation strategies need to be specific to different parts of Europe.

§ Biodiversity: Conservation strategies relevant to climate change can take at least two forms: in situ involving the selection, design and management of conservation areas (protected areas, nature reserves, NATURA 2000 sites, wider countryside), and ex situ involving conservation of germplasm in botanical gardens, museums and zoos.

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[73] Stern Review Report, p. 14
[74] European Environment Agency, 2005, Vulnerability and adaptation to climate change in Europe, p.7
[75] Adger, W.N., S. Agrawala, M.M.Q. Mirza, C. Conde, K. O'Brien, J. Pulhin, R. Pulwarty, B. Smit and K. Takahashi, 2007: Assessment of adaptation practices, options, constraints and capacity. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 717-743.
[76] For a summary of current adaptation practices in EU countries see, European Environment Agency, 2007, Climate change: the cost of inaction and the cost of adaptation; and European Environment Agency, 2005, Vulnerability and adaptation to climate change in Europe

- Agriculture: changes in crop species, cultivars or sowing dates; introduction of new crops and varieties, changing the allocation of agricultural land according to its changing suitability under climate change.
- Energy and transport
  - Energy: redesign of the energy supply system to the modification of human behaviour, enhancing the interconnection capacity of electricity grids and by using more decentralised electric generation systems and local micro grids, reduction of the exposure of energy users and producers to impacts of unfavourable climate through the mitigation of greenhouse gas emissions, for example by reducing overall energy use, shifting from fossil fuels to renewable energy use will be an effective adaptive measure.
  - Transport: reduction of emissions from transport through cleaner technologies and adapting behaviour
- Tourism: compensating for reduced snowfall by artificial snowmaking, introduction of new leisure industries, such as grass skiing or hiking; protection of resorts from sea-level rise by constructing barriers or by moving tourism infrastructure further back from the coast, promoting changes in the temporal pattern of seaside tourism, promoting new forms of tourism such as eco-tourism or cultural tourism
- Human health: development of health early warning systems and preventive emergency plans; mitigation of ‘heat islands’ through urban planning, the adaptation of housing design to local climate and expanding air conditioning, shifts in work patterns and mortality monitoring.

Such actions can be taken by individuals or households, local or national governments or at the supranational level (i.e. the level of the EU), depending on the scale of the negative effects, i.e. whether affects individual people or whole regions disregarding local and national borders, and depending on whether adaption practices generate a public good, which in economic terms is the main argument for national or EU wide adaption policies.

Still, according to the literature adaption practices the development and implementation of adaptation measures is a relatively new issue. Existing adaptive measures are very much concentrated in flood defence, which has enjoyed a long tradition of dealing with weather extremes. Concrete adaptation policies, measures and practices outside this area are still scarce.

Moreover the adaption planning faces considerable challenges when it comes to estimate the potential costs and necessity of adaption practices. These challenges are amongst others:

- Improvement of climate models and scenarios at detailed regional level, especially for extreme weather events, to reduce the high level of uncertainty. There exist still significant uncertainties associated with climate and non-climate scenarios required for impact, vulnerability and adaptation assessments,
- advancing understanding on 'good practice' in adaptation measures through exchange and information sharing on feasibility, costs and benefits,
- involving the public and private sector, and the general public at both local and national level,
- enhancing coordination and collaboration both within and between countries and between countries and sectors, to ensure the coherence of adaptation measures with other policy objectives, and the allocation of appropriate resources,

- filling the gaps in knowledge about the underlying causes of vulnerability and the theory of adaptation[77],
- increasing the still limited research on adaptation methodologies available for the quantification of their benefits, and particularly of costs[78]

5 Regional exposure to climate change

5.1 Vulnerability ranking of European regions

The IPCC assessment report 2007 defines vulnerability to climate change as the degree to which geophysical, biological and socio-economic systems are susceptible to, and unable to cope with, adverse impacts of climate change.[79] This definition comprises two different points. Firstly, vulnerability is defined through the sensitivity of a system to climate change. Thus, it takes into account how severe potential impacts of climate change might be. From that, the sensitivity to climate change of two different countries or regions is identical, if the impacts on both are equally strong.

Secondly, the definition also takes into account the ability of the systems to cope with those impacts. It follows, that even if the sensitivity of two countries or regions to climate change is identical, their actual vulnerability (or the differences therein) depends on their preparedness to adapt to climate change.

Such differences in vulnerability e.g. might exist between regions with different income levels (assuming that regions are equally sensible to climate change), as the more prosperous regions might find it easier to put the right measures in place. Differences in vulnerability between regions might also exist because of differences in endowments of human skills, physical infrastructure, administrative capacities or other factors like public awareness, private adaptation initiatives, the availability of financial incentives or instruments for adaption investments and so on.

All these issues, both with respect to the ability to cope with climate change, as well as with respect to the sensitivity to climate change – which covers at least as many aspects as the first issue – ideally should be reflected in one way or another when the EU regions vulnerability to climate change is analysed. Yet, for many of those issues there is a lack of knowledge (especially at the level of regions), making such a task difficult. Still, the attempt is made here, and despite scarce knowledge some data were collected that allow an analysis that is at least indicative of the potential vulnerability of EU regions.

The assessment of regional vulnerability is based on a summary index which combines seven indicators that are supposed to reflect one or more aspects of the regions vulnerability to climate change. In detail, the index is made up of the following components:

- an indicator of the regions vulnerability to drought
- the change in population affected by 100 year return river floods[80]
- the shares of agriculture, fisheries and tourism in gross value added or employment respectively
- the share of population living in coastal areas below 5m elevation
- the population density (to account for the heat island effect in cities)[81]

[77] European Environment Agency, 2005, Vulnerability and adaptation to climate change in Europe, EEA Technical report No 7/2005
[78] European Environment Agency, 2007, Climate change: the cost of inaction and the cost of adaptation, EEA Technical report No 13/2007
[79] Schneider, S.H., S. Semenov, A. Patwardhan, I. Burton, C.H.D. Magadza, M. Oppenheimer, A.B. Pittock, A. Rahman, J.B. Smith, A. Suarez and F. Yamin, 2007: Assessing key vulnerabilities and the risk from climate change. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, p. 783.
[80] using the results of the IPCC A2 model

§ information on the regions climate zones and temperature and precipitation changes (though both items flow into the index only indirectly)

§ regional GDP per head, reflecting the regions ability to adapt to climate change.[82]

Most information and data for the index is taken from the “Regions 2020” study. Though these data does not cover every aspect of the climate challenge as such (see above) it provides a solid basis, especially as it takes into account temperature changes that are the main cause for many of the effects that have not been covered by data. Furthermore the data in the “Regions 2020” study is – at least to the authors knowledge – a unique collection of climate related information at the NUTS2 regional level and as such for most parts not available via public data sources.

Notably, the summary index intends to give an overall picture of the regions vulnerability. Though the results it presents correspond to the projected climate related effects by the Stern review and IPCC report, it is the case that individual challenges within the overall climate change topic, that in reality can have very drastic effects on the population affected (e.g. floods) are somewhat put aside. To account for this the exposure to the individual challenges is illustrated via additional maps (one for each variable in the index) in the Annex.

In the calculation of the summary index, weights are not equally distributed across the various indicators. All but one variables were weighted equally, except for population density, which was given half the weight of the other variables to give more weight to the highly agglomerated urban areas[83].

The EU NUTS 2 regions were ranked according to the summary index into three groups, given their perceived vulnerability climate change. The three groups consist of one group of regions with low vulnerability, another regional group of medium vulnerability and regions with a high vulnerability. Importantly, low vulnerability does not mean that regions are immune to climate change, rather it is a relative measure, indicating that those regions are affected but compared to highly vulnerable regions to a lesser extent.

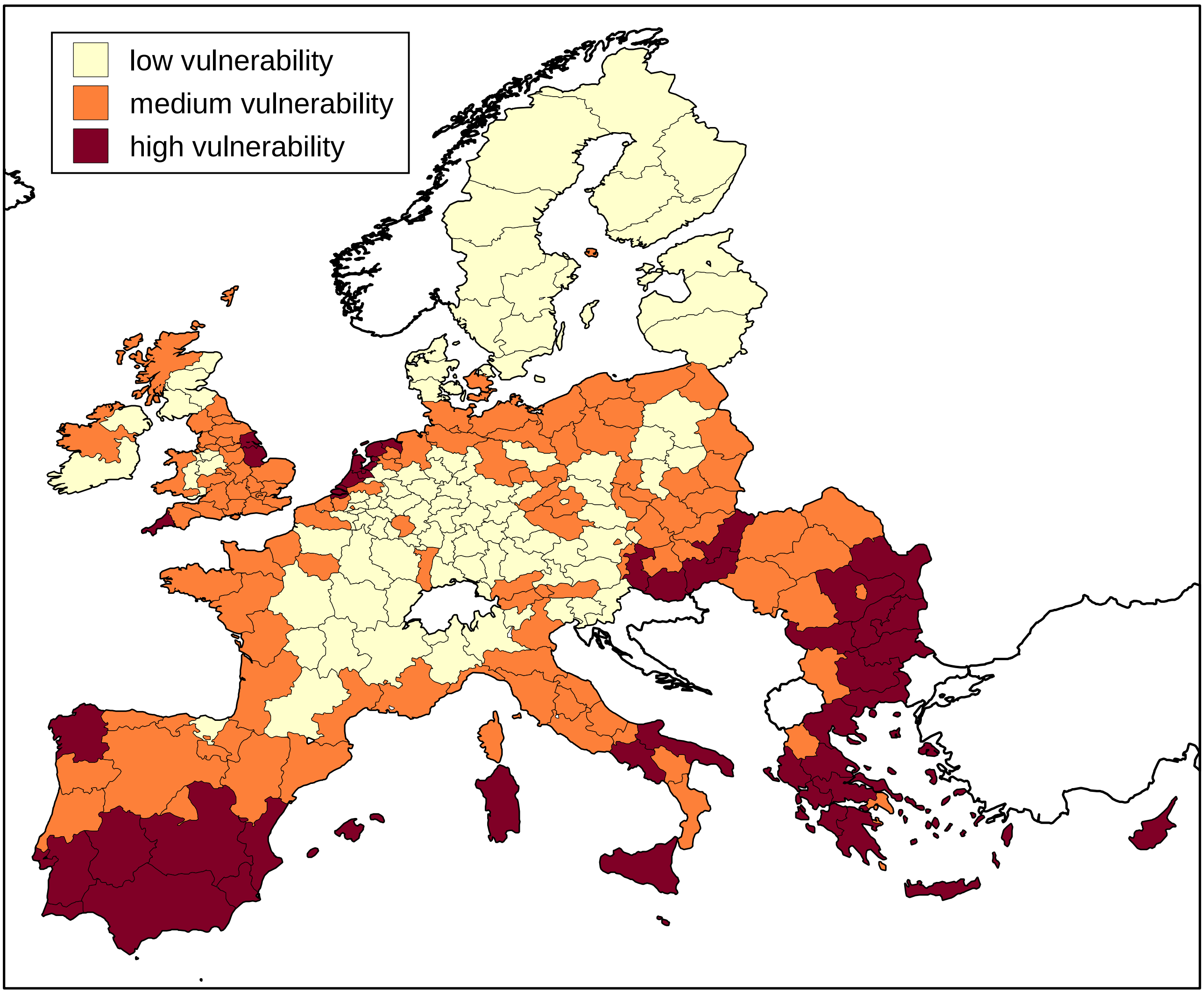
5.2 Main patterns of vulnerability in the EU

Figure 13: Regional vulnerability to climate change

[81] population density is taken in logarithms to reduce variability.

[82] other factors like skills, infrastructure etc. are not taken into account. Firstly, regional GDP in many cases tends to be correlated with other variables that might be used here. Thus high income regions in most cases have a higher average skill level than less prosperous regions. Secondly, for other variables the right measure is difficult to define. Looking at skills again, it is the question whether it is indeed the number of people with university degrees that make a difference in the ability to adapt, or whether it is more the number of people with university in natural science, or the number of people (with our without degree) working in the area of adaption etc. Similar hold for infrastructure and potential other variables. The main point is that the more detailed and the more accurate the analysis gets the harder it is to find or define the right data. For that further research is needed.

[83] This is because the distribution of population density shows only few regions with a population density of more than 2000 inhabitant per square km. The reduction of the weight for the population indicator decreases the value with which this indicator enters the summary index, whereby the densely populated areas (i.e. major cities) still show an effect on the overall indicator, while the effects of the less densely populated areas is negligible.



As mentioned, the summary index reflects to a considerable extent the consensus findings in the recent literature. Thus the majority of highly vulnerable regions as located in the South, in the Mediterranean and Black Sea area, while the least vulnerable regions are found in the North and in Central Europe. In more detail:

§ Regions with high vulnerability: The majority of the regions in this group are coastal regions, located either located at the Mediterranean sea, like a number of Spanish, Italian and Greek regions also including Malta and Cyprus, or at the Black Sea like the Bulgarian regions and the Sud-Est region in Romania or at the Atlantic (Portuguese regions), the North Sea (Dutch, Belgium and UK regions). A common feature of all those regions is their particular vulnerability to a rise of the sea level combined with potential losses in the fishery industry. In addition the Southern regions are also particularly vulnerable to increases in temperature that is likely to intensify and increase the number of droughts and to have negative impacts on the agricultural sector, which is of particular importance in Bulgarian, Greek and Spanish regions. Furthermore the same regions, being important tourist destinations, might see additional economic losses through a decline in tourist arrivals, or at least they might undergo a significant structural change if the main tourist season shift from summer to spring and autumn. By contrast, the Northern coastal regions face dangers from floods -most of the UK and some Dutch regions, while all North Sea regions in mainland Europe potential (economic) damages from floods or a rising sea level are presumably higher than elsewhere, given that these regions are highly populated areas with a dense business activity.

§ Regions with medium vulnerability: These are spread all over Europe (except the North), especially in the UK, France and Italy, Central and Eastern Europe (including Austria) and the Northern parts of Spain and Germany as well as Denmark. The particular reasons for their specific vulnerability are just as diverse. Thus the danger of floods is very high in a number of regions in the UK, Hungarian, Czech, Romanian and some French and Belgium regions, while potential negative effects of an increase of the sea level could arise in the coastal regions. Potential negative effects from droughts can be expected for some UK, Spanish, Hungarian regions, while negative effects in agricultural production will mainly affect the Polish and Romanian regions. A potential decline in fish stock will mostly harm the Italian, Spanish and Scottish regions and negative consequences for tourism are likely to occur especially in Austrian alpine areas but potentially also in capital cities like Prague, Rome and Vienna because of an over-proportional increase in temperature in large urban agglomerations.

§ Regions with low vulnerability: These regions are geographically more concentrated, mostly in Central Europe (Germany, Eastern parts of France, Southern part of Belgium) and Northern Europe (Scandinavia, the Baltics and also main areas in Poland). Despite their low vulnerability, if compared to other regions, these regions are not immune to climate change. Thus, floods could pose major problems in the Czech and French regions. As before the coastal regions especially in Sweden and Finland might suffer from rising sea level and structural shifts in the fishery sector.

6 Analysis of impacts of climate change on regional disparities

The analysis of the impacts of the climate change challenge on regional disparities within the EU will be done with two alternative scenarios. This is daring. Climate change is uncertain. This is partly because our understanding of climate change and its impacts is incomplete, but it is also because climate change will take place in the future, driven by future emissions, and impact upon a future world.[84] Furthermore, the authors of the IPCC Special Report on Emissions Scenarios (SRES) (that is the base for many climate change analysis) highlight “that the current literature analysis suggests the future is inherently unpredictable and so views will differ as to which of the storylines and representative scenarios could be more or less likely. Therefore, the development of a single "best guess" or "business-as-usual" scenario is neither desirable nor possible. Nor should the storylines and scenarios be taken as policy recommendations.”[85]

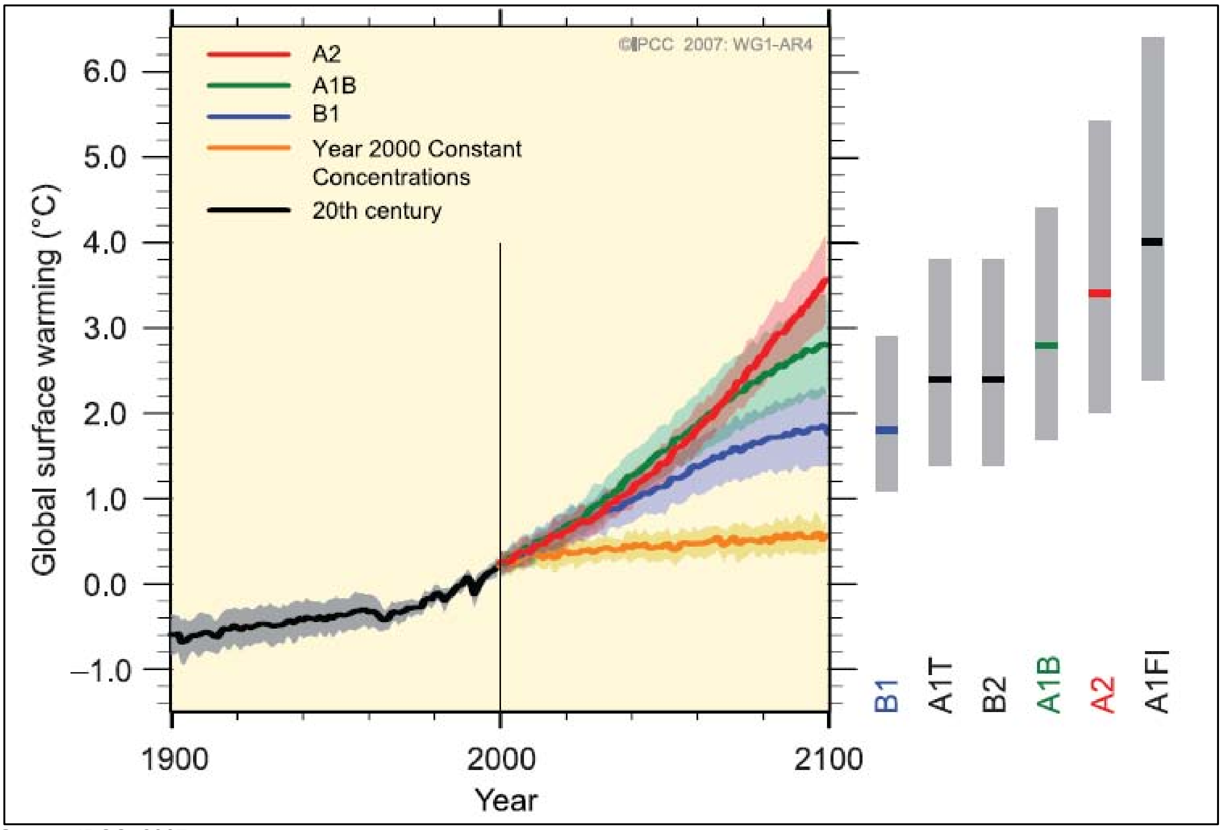
The SRES team constructed a set of 4 alternative scenario "families", whereby each family was based on different, alternative interpretations and quantifications of demographic, social, economic, technological, and policy future. Within each family another set of alternative scenarios was defined, so that in total 40 different scenarios where available.

From this abundance of available alternatives, that in one way or another creates a certain inconclusiveness on what the effects of climate change really are, the incomplete understanding of climate change itself remains a major difficulty, in particular the regional effects of climate change, and specifically the coverage across the range of different climate change effects,[86] when it comes to measure the (economic) effects of the climate change challenge.

[84] European Environment Agency, 2007, Climate change: the cost of inaction and the cost of adaptation, EEA Technical report No 13/2007 p. 28
[85] IPCC, 2001, IPCC Special Report on Emissions Scenarios, chapter 4.
[86] European Environment Agency, 2007, Climate change: the cost of inaction and the cost of adaptation, EEA Technical report No 13/2007 p. 7

To illustrate Figure 14 shows the likely range of global warming that the various climate models predict. From this it is obvious that, no precise guess can be made about what the future global warming will actually be. The range of global warming is from around 1.8°C to around 4°C, depending on the model, whereby each model itself has a significant amount of uncertainty or variability, so that it can not be excluded that temperatures rise 6°C above pre-industrial levels.

Figure 14: Best values and likely ranges of global mean warming for the time horizon of 1900-2099 relative to the control period of 1980-99.



Source, IPCC, 2007

At the same time Figure 14 also shows that over the short period, i.e. until 2020 there is not much variation across the models, as temperatures are expected to increase by around 0.5°C in all the simulations.

This creates another difficulty for building two different scenarios for the time horizon up to 2020.

Moreover, the above analysis has demonstrated that climate change is a multi-dimensional challenge, making it inherently difficult to take into account all of its dimension and nearly impossible to analyse the interrelationship and inter-linkages between two ore more of those dimensions.

The analysis is further limited by the fact that in the literature any estimates with respect to potential socio-economic impacts are to be treated with caution. Thus, as stated by the EEA, despite increasing efforts being devoted to research on various aspects of the economics of climate change in Europe, there is limited confidence in the magnitude and rate of estimates. Knowledge on the potential impacts of the economic changes on natural and human systems is not yet detailed enough and there are important evidence gaps. Much of this relates to the quantification of impacts and costs, but it is also strongly affected by methodological issues.[87]

[87] European Environment Agency, 2007, Climate change: the cost of inaction and the cost of adaptation, EEA Technical report No 13/2007p. 57

Therefore, as climate scenarios are extremely heterogeneous, uncertain and complex, the following analysis has to be taken with extreme caution as it covers only a small part of all potential effects, and moreover -given the limited space available- only in highly aggregated fashion.

6.1 Main hypotheses for future scenarios

In the light of the above arguments it does not seem promising to create two scenarios using two different assumptions about likely future temperature increases, especially not with respect to the time horizon of 2020, as climate models have shown not much variation in this regard.

However, there is a point to be made if it is taken into account that global warming not only means a continuous increase in the mean temperature, but also causes (increases) changes in the variability of weather. Though both phenomena affect the EU regions, they do so in a differentiated way. A continuous, steady increase in temperature can be assumed to affect the regions basically along the lines of the literature reviewed above. Thus, temperature increases will be felt most in the Southern and coastal regions in economic, social and environmental terms, while Northern regions even might benefit from global warming in some respects, provided that temperature increases are not too high.

The situation is different if climate variability increases, and hence the number of extreme events like heat waves, droughts, floods or storms that may affect each region independent of their vulnerability to a steady increase of the temperature. E.g. referring to Figure 2 above it is shown that heat waves are likely to affect especially those regions that at least to the regional vulnerability index are considered to be of low or medium overall vulnerability to climate change.

As a consequence, depending on whether climate change is a steady process or comes as an increase of extreme events, the implications for the regions differ with respect to the economic, social and environmental consequences and hence the need for adaptation to avoid them.

From this is appears to be a fruitful approach to build the two scenarios around this storyline.

Hence the first "steady" scenario assumes that climate change causes a continuous increase of the temperature, while the second "erratic" scenario assumes that climate change effects (at least up to 2020) mainly will be felt through a higher number of extreme events.

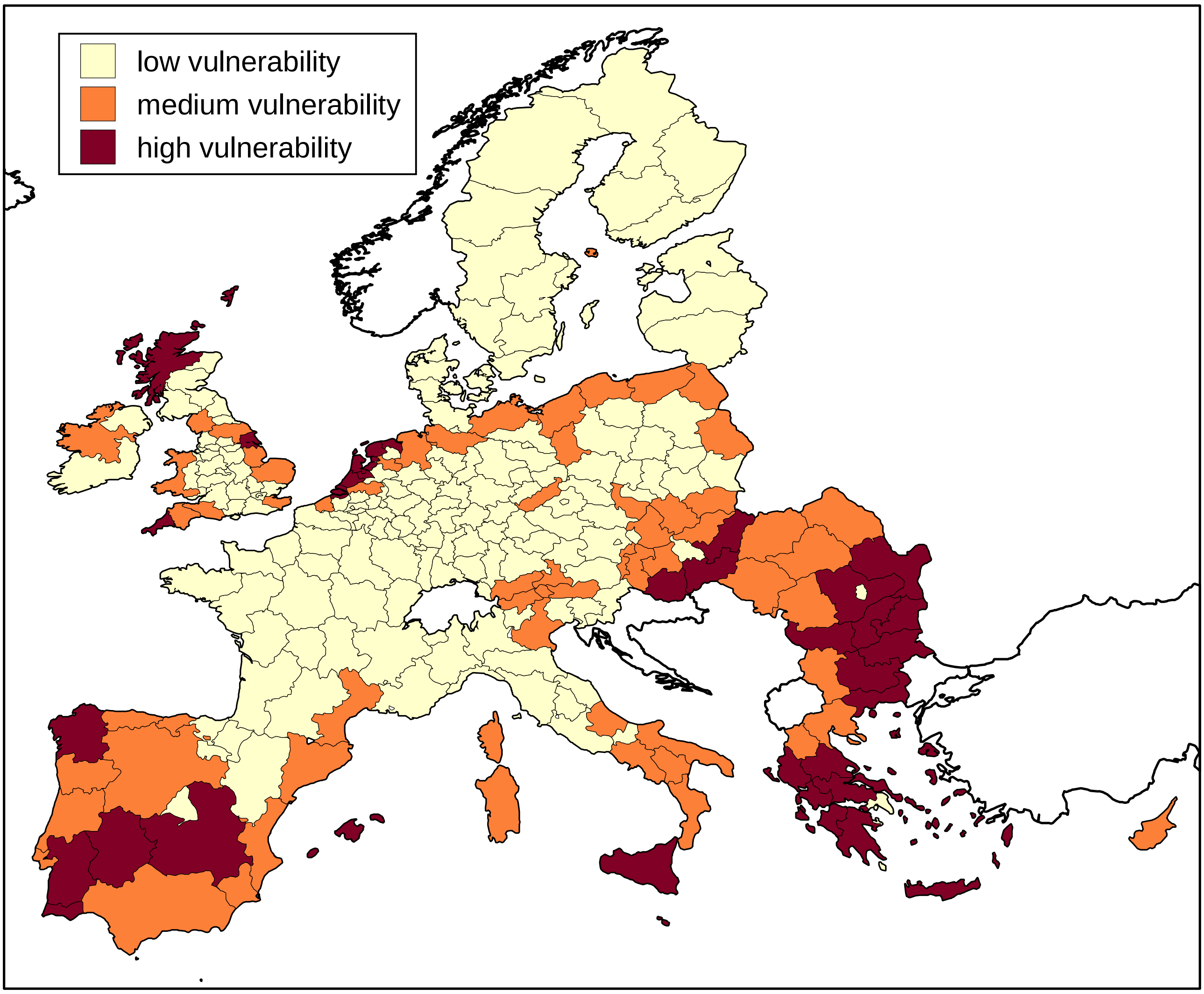
6.2 Steady scenario

As outlined, the steady scenario assumes a continuous increase of the temperature, whereby in order to focus the scenario exercise it is assumed that extreme events do not play a role. The impact of this upon the EU regions is illustrated by recalculating the vulnerability index above, putting more weights on those variables that are assumed to be affected most in this scenario, i.e. the shares of agriculture, fisheries and tourism as well as the share of population living in coastal areas below 5m elevation. Regional GDP per head was weighted the same way in order to reflect adaption capabilities properly, while all other variables were given less weight[88].

The vulnerability index for the steady state scenario is presented in Figure 16[89].

Figure 15: Regional vulnerability in case of a continuous increase of temperature

[88] They were not set to zero, because they are assumed to reflect mostly, but not exclusively extreme events.
[89] The thresholds for grouping the regions into the high, medium and low vulnerability group are identical to the overall vulnerability index above.



Comparing it to the overall vulnerability index above, it is evident that a steady increase in temperature has – at least in relative terms – much less effects on the EU regions compared to if both a steady increase and extreme events are taken into consideration.

Thus, there is only a relative small number of regions (12% of the EU regions) that are in the highly vulnerability group. These are especially the coastal and/or Mediterranean and Black Sea regions as well as Southern Hungarian regions. Similar, also the medium vulnerable regions are mainly found to be coastal regions, especially in the EU15, as well as a number of Central and Eastern European regions (in the Czech Republic, Slovakia, Hungary and Romania) because of their low income levels and the inferred lack of adaptation potential. By contrast, the large number of low vulnerable regions suggests that, with respect to a steady temperature increase, most of the EU regions might be affected by this type of climate change, but the potential impacts could be manageable with some adaption efforts.

Still, the question remains what the actual impacts of a steady increase of the temperature will be on the regions, regardless of their vulnerability status. In principle, the effects will be along the lines of the literature reviewed above (like a decrease of crop yields, reduced supply of water, effects on biodiversity, economic effects on energy, tourism etc.). Yet, until 2020, it is questionable whether the increase of 0.5°C that is expected by most climate models, will have serious impacts on the regions.

Though it is not clear what the effects will be until 2020, it can be assumed hat shifts in global temperature will necessitate significant **redistribution efforts** within the EU, from regions less affected to regions highly affected by climate change. The scope of this redistribution might be large (though potentially not by 2020) and might cover economic aspects (energy and incomes), social aspects (emigration from highly affected regions) as well as resources (e.g. water and food).

6.3 Extreme events scenario

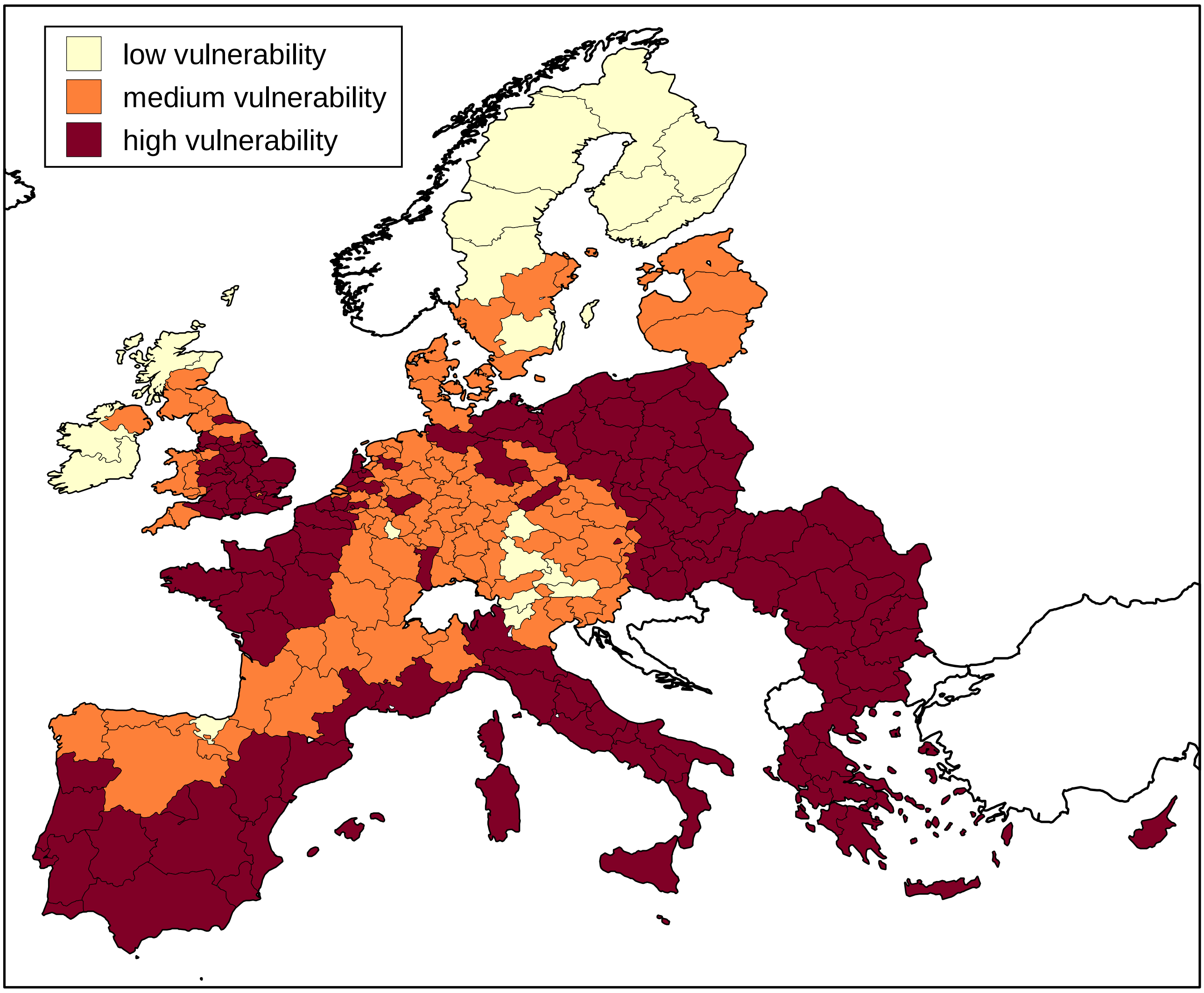
To analyse the regions vulnerability in the case of climate change causing an increase in the number of extreme events, we, again, recalculate the vulnerability index. This time we put more weight on those indicators connected to extreme events, namely: the regions vulnerability to drought, river floods and the population density (to account for the heat island effect in cities). Regional GDP per head was weighted the same way in order to reflect adaption capabilities properly, while all other variables were disregarded, to focus exclusively on the vulnerability to extreme events. The extreme events index is presented in Figure 16.

Putting a focus on extreme events reveals a significant change of the perception of the regions vulnerability to climate change. In fact Figure 16 suggests that all but a few regions in the EU are likely to suffer to a considerable extent from extreme events.

Thus, vulnerability is highest in the Southern regions (Portugal, Spain, South of France, Italy, Greece), as well as in most Central and Eastern European regions, partly because of their low adaptation potential. Vulnerability is also high in the North of France and Germany and in the Southern parts of the UK. While the most of the Northern regions, including Poland, are potentially vulnerable to floods and storms, the Southern regions, including Hungary, Bulgaria and Romania, are also vulnerable to floods but at the same time to droughts, as the seasonal variability of rainfall increases in the winter, while heatwaves will get stronger during the summer months, carrying with them all the negative consequences described in detail above.

The importance of taking into account extreme events, when analysing the effects of climate change, is also shown by the large number of central regions that are medium vulnerable, at least as defined as by the index in use. Thus, virtually all, but few EU regions are either highly or medium vulnerable to extreme events.

Figure 16: Regional vulnerability to extreme events



As a consequence, and to summarize the results of both scenarios, the perception of climate change differs widely depending on whether it is assumed that global warming will be a continuous process, without major changes in the climate variability, or whether global warming causes a higher frequency of extreme weather events.

The existing evidence and climate models suggest that climate change will and already is in fact a mixture of both, though there is potentially a difference in the timing. The negative effects of extreme events are likely to occur in higher number much sooner, while the temperature is expected to increase relatively slowly and hence negative impacts will be felt later in the future.

For that action to combat climate change is needed already now. This is obvious for mitigation issues as any measures taken now, though already being late, serve to reduce the negative impacts in the future. It might be less obvious for adaptation measures, but considering that extreme events will strike most EU regions already in the near future, leaves no doubt that we have to be prepared as good and as soon as possible to prevent major damage to our economy, environment and lives.

7 Annex

Figure A1: Population affected by river floods

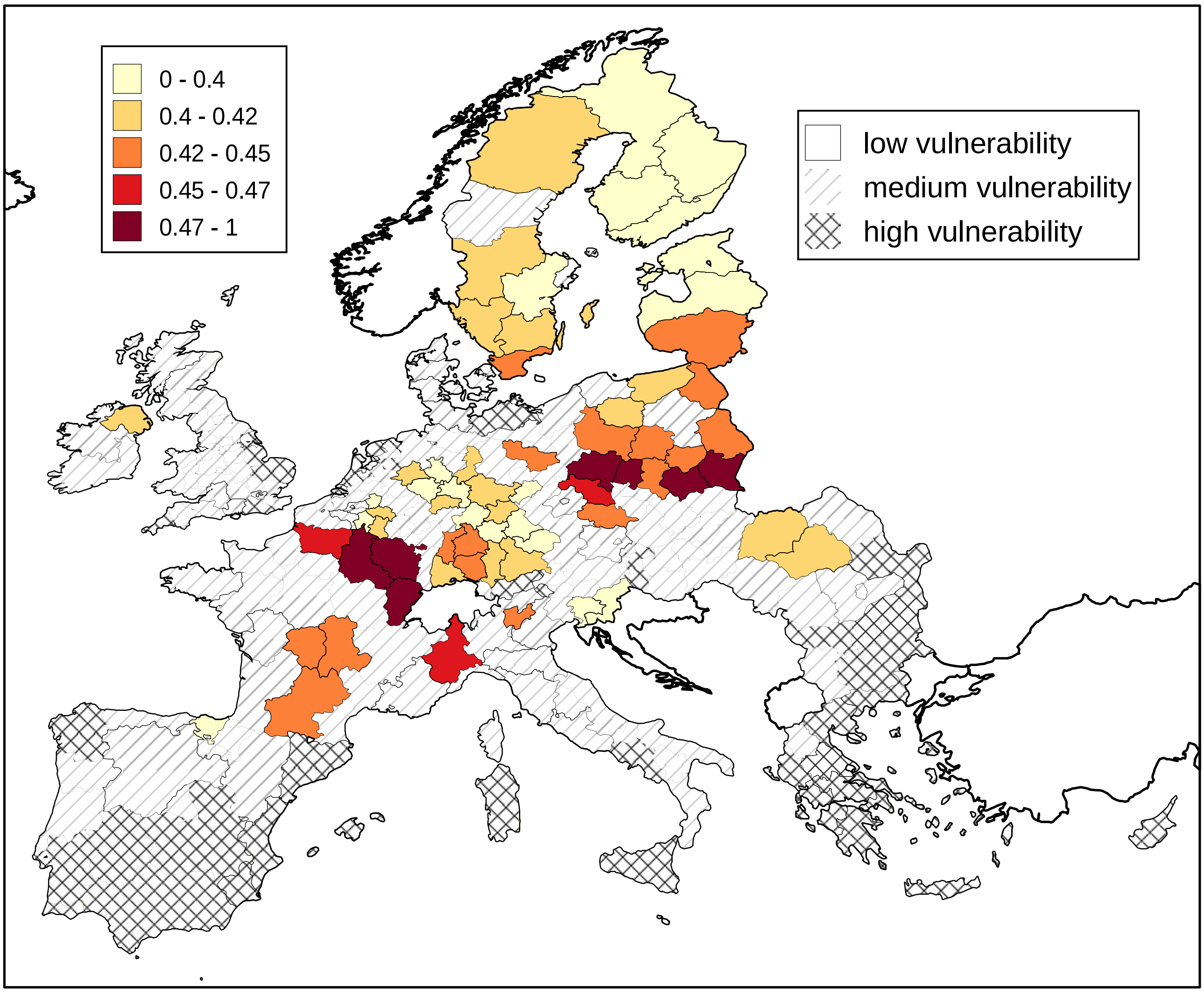


Figure A2: Population living in coastal areas below 5m elevation

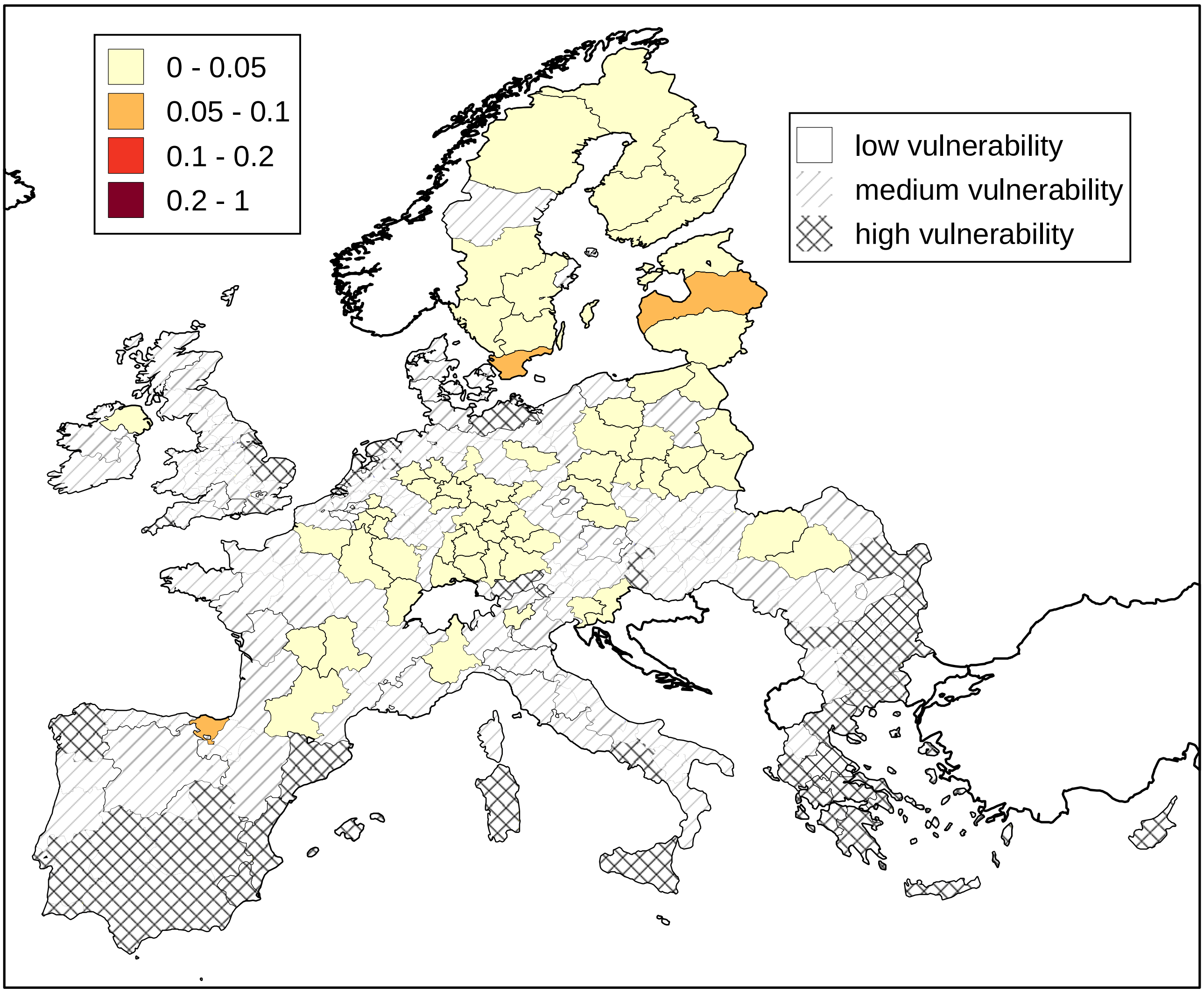


Figure A3: Vulnerability to droughts

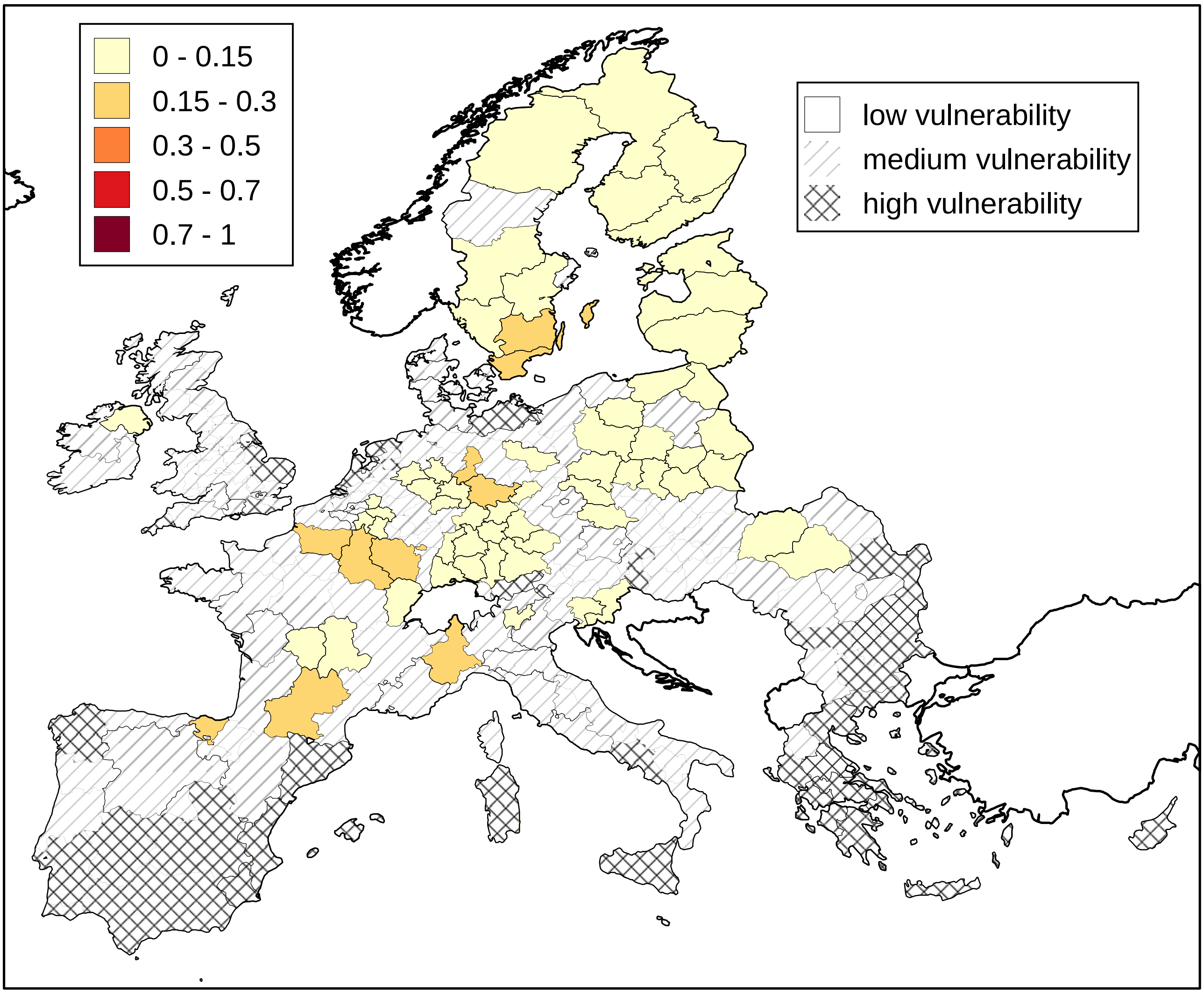


Figure A4: Vulnerability of Agriculture

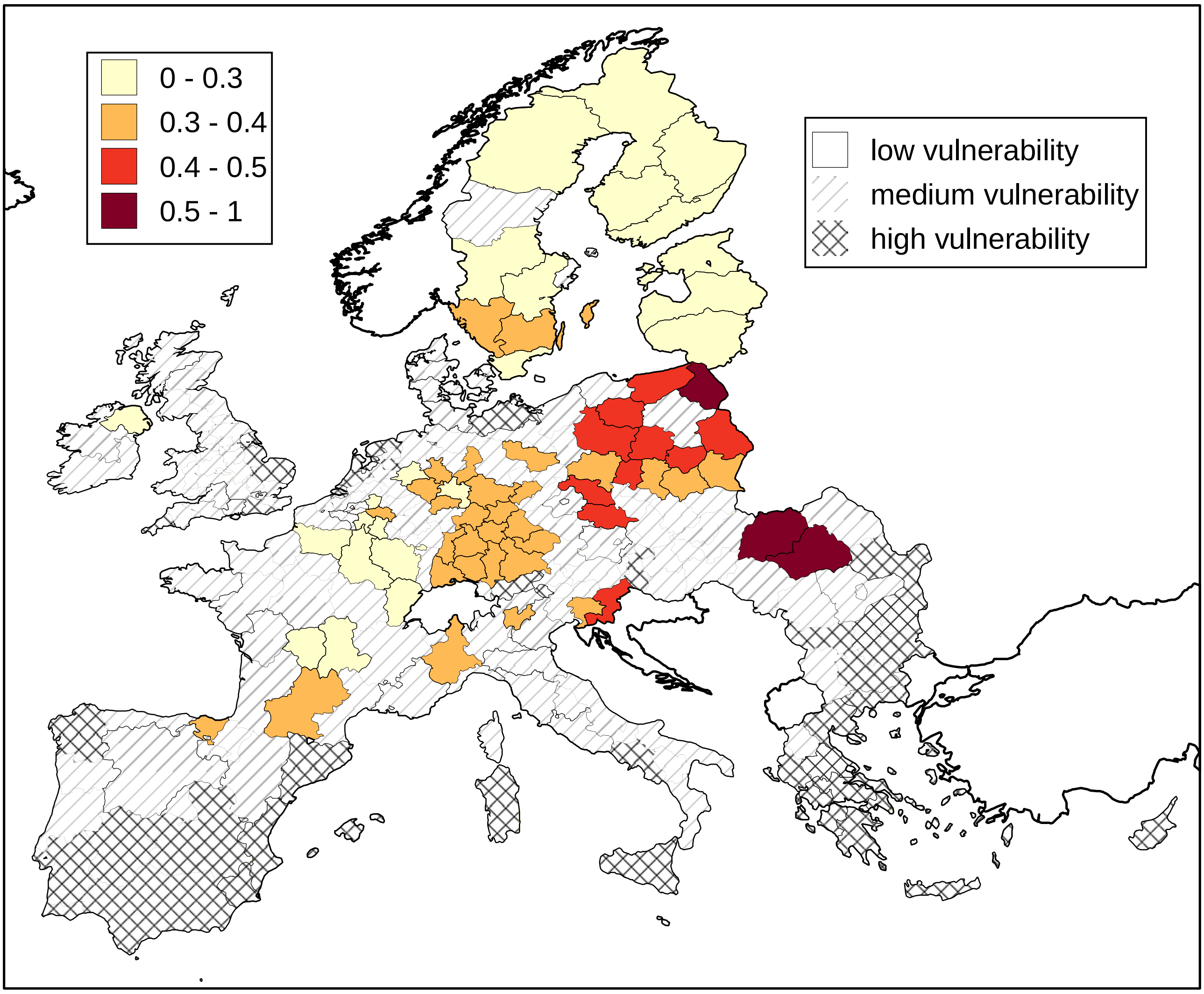


Figure A5: Share of tourism in total employment

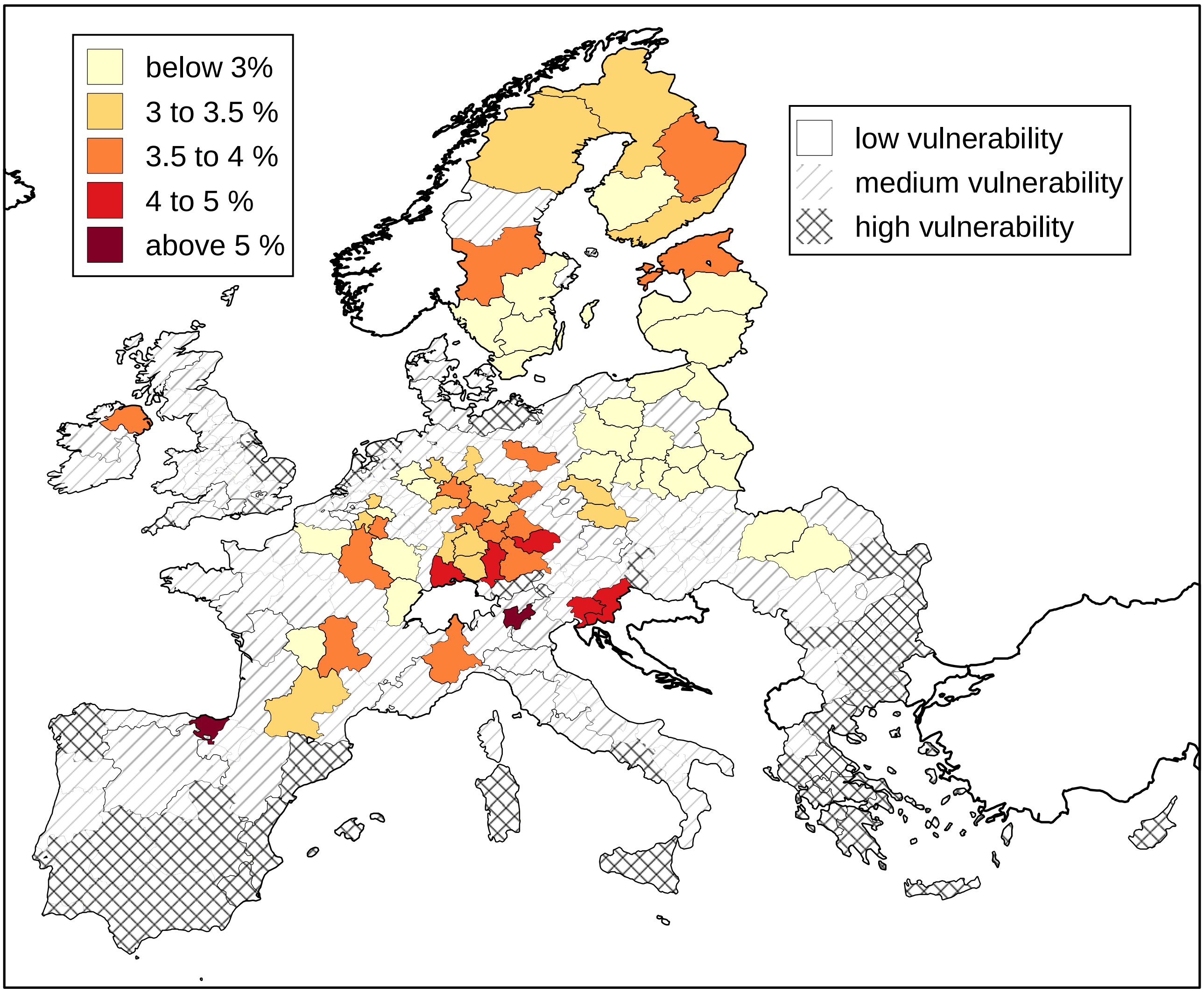


Figure A6: Share of fishery in total employment