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DEMIFER

Demographic and migratory flows affecting European regions and cities

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Deliverable 8

A Report on Climate Change and Migration

Prepared by

Philip Rees, Pia Wohland and Peter Boden

School of Geography, University of Leeds

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This basic report exists only in an electronic version.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

This document assesses the impact of climate change on migration for Europe. The report reviews the British, European and international literature. The review leads us to be sceptical about the size of potential climate refugee flows to Europe. Most case studies show climate change induced displacement is local in scale and therefore unlikely to add to immigration from outside Europe. We focus therefore on the impacts of climate change on potential displacements within Europe. We look at the impacts of six climate change indicators: change in mean annual temperature, change in mean winter precipitation, change in mean summer precipitation, change in the annual number of days with heavy rainfall, change in the number of days of snow cover and sea level rise. Key findings are as follows. In the second half of this century 108 million people will live in the 'Warm temperate Mediterranean climate zone', where big rises in temperature and big falls in summer rainfall are projected. Richer people will be able to adapt through seasonal migration. The difficulties of climate change will be experienced by those unable to adopt a seasonal circulation. In the 'Cold temperate and montane climate zone' big changes are anticipated but these will affect a relatively small population of 17 million. The change in annual number of days with snow cover will have serious impact on winter resort settlements, but regional populations are small. The other climate zones will experience less extreme changes. No substantial effects on migration are expected. Mitigation measures over the next nine decades will have to be taken, of course, but Europe should not experience major displacements.

ACKNOWLEDGEMENTS

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1. INTRODUCTION

In this document we report on our assessment of the likely impact of climate change on migration in Europe. This is a very difficult task (if not nigh impossible) and much of what we say is judgemental rather than firmly based on evidence. Nevertheless, the question of how much impact climate change might have on future population displacements is so important that it is worth attempting an answer, no matter how provisional and tentative that might be.

In the DEMIFER project we have put together with Transnational Programme Group colleagues in IOM/CEFMR (Warsaw) and NEAA (The Hague) a system for analysing the future population of Europe. The system consists of an innovative demographic projection model (Deliverable D4), a set of reference scenario projections for European NUTS2 regions based on a benchmark set of estimates of population dynamics around 2005 (Deliverable D5), a set of policy scenario inputs for each of five demographic components for driving the projection model (Deliverable D6) and an analysis of the projection results using innovative graphics and mapping for the regional outcomes (Deliverable D7). We used this system for running an extended Limited Social Europe (LSE) scenario that carries our projections forward from 2050 to 2100.

The plan for this document is as follows. In section 2 we review the literature on population displacement in general and assess to what extent it can be linked to climate change. This review concludes with a description of the scenarios of climate change used by the Inter-governmental Panel on Climate Change (IPCC) and the features of the scenario chosen for use. In section 3 we describe our methods for bringing together the results of the climate scenario and the population scenario. In section 4 we present the results of IPCC B1 scenario at NUTS3 scale (Greiving *et al.* 2010) mapped onto our projections of population at NUTS2 scale. We conclude section 4of the report with a discussion of the possible impacts for each of the five climatic regions proposed by the ESPON Climate Change project. In a final section we summarise and reflect on our findings.

2. CLIMATE CHANGE AND MIGRATION: A REVIEW

The objective of this section of the report is to identify key publications which evaluate the potential impact of climate change upon migration, both within countries and between countries. Of particular interest is the potential impact upon Europe, which includes the effect of climate change on European countries and the potential impact from displacement elsewhere in the world. The literature is reviewed at three levels: UK, European and International. In reviewing the literature, we try to understand who the Climate Change migrants are and what climate change processes might cause population displacement (e.g. global warming, floods, sea level rise). Climate change takes place against a background of continuing though slowing population growth in developing countries. Adaptation strategies are important to consider as well because mitigation actions (e.g. building a bigger dyke) may substitute for migration. The migration policies of European and of developing countries are germane and are assumed in our LSE scenario to be fairly restrictive.

Table 1 sets out the most inclusive estimate of population displacement over the next forty years. The estimates are very large indeed, about 22 million per year between 2000 and 2050. This estimate puts climate change displacements second in rank after development project displacements (e.g. the 1.2 million official displaced migrants caused by the Three Gorges Project that dams China's Yangtze River/Chang Jiang). A figure of 250 million is proposed or about 5.5 million per year. All these estimates are based on huge assumptions and should really be regarded as equivalent to the numbers we use in our policy scenarios.

Table 1: Estimated population displacement to 2050 (in millions)

Reason for Population Displacement	Total (millions)	Per year 2000 to 2050
Conflict and extreme human rights abuse	50	1
Natural disasters	50	1
Development projects (dams, mines) at current rate of 15 million per year	645	15
Climate change phenomena such as floods, droughts, famines and hurricanes	250	5
People who flee their own country to be accepted as refugees	5	0.1
Total	1,000	22.1

Source: See references in Christian Aid (2007) for the justification of the numbers.

2.1 Climate change: the World perspective

The Guardian (2007) reports that the UN predicts that 1 billion people could be displaced by climate change with 155 million currently affected by conflicts, development projects and natural disasters. There is thus an additional 850 million increase expected, based on the numbers expected to be experiencing water shortages, sea level rises and decreases in productivity. BBC News (2009) argued that climate migration fears were misplaced. The poorest people affected by climate change events will not migrate to richest countries due to displacement by climate change because they do not have necessary resources. Short term and short distance migration is more likely as it has always been an adaptation strategy of the poorest and must be seen as part of an international solution. The Times (2008) also commented critically on the UN predictions that fear will increase of refugees displaced by conflicts, environmental degradation due to climate change and future conflicts over water due to climate change increasing droughts.

Barnett (2009) in *Nature Reports* reviews the important research by Warner *et al.* (2009) on *In Search of Shelter*. This is the first piece of research conducted on climate driven migration which shows that that most migration will be *regional* rather than international in its impact. The reason is that people most affected by climate change events are unlikely to have the means to move very far. As climate change becomes more intense environmental degradation will occur and this will make the displacement permanent rather than temporary.

Lutz (2009) discusses the contribution that demographic analysis can make to understanding of the relationships between population and climate change. He highlights the need to strengthen human capacity through education which also reduces population growth and enhances economic growth. This is seen as the most promising investment for adaptation to climate change. He cites the *WHO Report on Climate Change and Human Health:* "In general, countries with more 'human capital' or knowledge have greater adaptive capacity. Illiteracy increases a population's vulnerability to many problems." Research has shown that changes in population growth, age structure and spatial distribution interact closely with the environment and with development. Rapid population growth has exacerbated freshwater depletion, climate change, biodiversity loss, depletion of fisheries and other coastal resources, and degradation of agricultural lands. Fertility decline, driven in part by women's increasing participation in education at all levels, slows population growth.

Boncour and Burson (2009), in their study of the South Pacific region accept that there is no definition of an environmental migrant. The term environmental refugee is in widespread use but does not have any basis in international law. Environmental events have long had an impact upon migration (e.g. floods), which makes it difficult to assess the role of climate change per se on migration. Migration has been seen as a problem yet it is an important part of the adaptation strategy and has been for millennia when societies are faced with environmental degradation. There is a need to understand the pattern of migration as both a fast process (in response to a climatic event such as a storm) and as a slow process of adaptation to a changing environment.

Brown (2008) points out that the prediction of around 200 million people displaced by 2050 due to climate change is widely repeated (the Table 1 estimate was a little higher) but is really only a rough guess. He highlights the factors that affect the interaction of migration and climate processes such as sea-level rise and events such as floods that combine with human factors such as governance to increase vulnerability. Adaptation measures are needed globally: the problem needs to be recognized and policies designed that decrease vulnerability in developing nations and keep skilled labour in these countries. Emphasis on coastal defence and regional centre development in vulnerable location is needed, he argues.

The important report by Warner *et al.* (2009) researches the extent to which climate change is already contributing to displacement and migration. Environmental, economic and political factors combine to force movements. Conflicts over resources such as water influence migration, particularly in the Sahel region. Disasters lead to shorter-term displacement and migration is a survival strategy. Seasonal migration is already a key adaptive measure used in many countries affected. Climate change is likely to lead to long term migration when it affects whole livelihoods.

The Refugee Studies Centre (2008) has published a report entitled *Forced Migration Review, Climate Change and Displacement*. The papers in the collection argue that climate and environmentally induced migration will become a key issue over the next century. Poverty, failing ecosystems, vulnerability to natural hazards and gradual climate-driven environmental changes are all linked to environmental migration. Warming will affect agricultural productivity, natural disaster such as floods will cause mass displacement and sea level rise will destroy productive low level lands leading to more mass displacement. The authors cite the UN prediction of 200 million migrants displaced by climate change. The authors identify a need to improve predictions and to solve the problem of distinguishing the role of climate change from other environmental, economic and social factors. Climate change is likely to increase numbers that migrate to urban areas. The report highlights the need for a clearer definition of environmental migration. It is widely believed that the majority of people who flee natural disasters remain in their own country. There is the obvious need of humanitarian assistance but they do not fear persecution and so cannot be termed refugees. The European Court of Human Rights ruled that governments must enact laws to mitigate risks posed by climate change.

The report by Christian Aid (2007) on *Human Tide: the Real Migration Crisis* estimates that 5 million people will flee their own countries and be accepted as refugees. Spread over 45 years and all continents suggest that the numbers likely to come to Europe will be small.

The Environmental Justice Foundation (EJF 2009) suggests that the majority of people caused to move as a result of climate change events will be internally displaced, migrating only short distances from home. Relatively few are likely to migrate internationally and settle permanently in other countries. With no internationally recognised legal term for people who migrate as a result of environmental degradation and climate change, the authors argue there is the need for a new protocol under the United Nations Framework Convention on Climate Change to address the needs of climate refugees.

2.2 Climate change: the European perspective

Government Office for Science (2010) in its *Foresight Land Use Futures Project* considered potential impacts of climate change on land use. One impact will be the move towards a low carbon economy which will influence land use decisions, settlement patterns, design of urban areas and transport infrastructure. Increased flood risk will have implications for building in coastal areas and on floodplains. Without any increased flood protection, the report estimates that 800,000 homes will be at risk rather than the current 500,000. Of course, policies for reducing carbon dioxide emissions will mean a significant increase in renewable technology needed to meet EU 2020 target of 20% energy generated from renewable sources with land use implications. There is a need for approval of more wind farms and a need for more land to be converted to bio-fuel production (Mackay 2009). However, this climate change is unlikely to generate more than a few very local migrations.

European Commission (2008) examined the effects of climate change and highlighted particular pieces of EU legislation, such as the need to manage flood risks to help mitigate the potential effects. The document stresses the need for action at all levels in the EU from individuals to councils to regions. EU strategy should be based on solidarity for affected member states, regions and other countries outside the EU. The report highlights a range of consequences of climate change from effects on natural ecosystems to climate refugees, citing predictions of 1 billion people migrating due to climate change by 2050.

The European Commission has funded important research on the ground where climate change impacts are being felt. EACH-FOR (2008) looks at common problems within some European countries such as water shortages and desertification. The researchers indicate the problems of climate change will lead to out-migration from areas within European countries as temperature increases. In Spain and Portugal rises of 5 to 7 degrees Celsius are projected, making the Iberian peninsula the most affected area in Europe. A case study of Turkey shows the effect of development projects on migrants. Some 28 villages and 48 hamlets affected by the building of the Ataturk Dam in central Turkey were given the choice of either compensation and self relocation or relocation by the state. Relocation occurred from the south east of Turkey to the west of Turkey. The Ataturk dam also affected traditional agriculture that relied on groundwater leading to seasonal migration. Whether we can classify these events as a direct effect of climate change is debatable, but they do illustrate that the displacement effects occurred within the country rather than to Europe.

European Commission (2009) highlights two kinds of responses that are needed to adapt to the threat of climate change. The first is to reduce greenhouse gas emissions and the second is to adapt to unavoidable consequences of climate change. Increasing the resilience of Europe to climate change will involve investing in renewable technologies as part of the Economic Recovery Plan. The paper highlights the most vulnerable regions as Southern Europe and the Mediterranean basin, with coastal regions being most severely affected due to failing crops, lack of access to water resources and rising temperatures. The White Paper recommends action against climate change needs to be taken at local, national and regional levels but it requires support and integration for the EU to make a coordinated approach.

Bogardi (2007) highlights key areas of vulnerability due to climate change. His world desertification map shows a high risk in Southern Spain and a moderate risk in Greece. Maps in the report show the vulnerability of areas to sea level rise with the coasts of the Netherlands, Denmark, northern Germany and the east coast of Britain likely to be affected by a sea level rise of 1 metre.

IPCC (2007b) discusses the key challenges Europe will face from climate change: winter floods are likely to increase, sea-level rise will affect an additional 1.6 million people a year, differences in water availability between areas with water stress increasing over central and southern Europe with 35% under water stress by the 2070s. The report also mentions a number of non climatic factors that will affect Europe with a prediction that the population will decline by 8% from 2000-2030. The proportion of the population of EU15 that is over 65 is expected to increase from 16% in 2000 to 23% in 2030. We, of course, have taken the view in our policy scenario projections that the worst case is that the European population remains stationary, principally because other projections have under-estimated the potential for improvement in life expectancy.

EEA (2008) summarises the key features of European climate change and future threats. Temperature is predicted to increase in Europe between 1.0 and 5.5°C by the end of the century, higher than projected global warming. Droughts and water stress will increase, particularly in the south and in summer due lower river flows. Annual precipitation changes are already exacerbating differences between a wet northern part (an increase of 10 to 40 % during the 20th century) and a dry southern part (a decrease of up to 20 % in some parts of southern Europe). The report estimates that 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. The large number of additional deaths during the 2003 summer heat wave (more than 70 000 excess deaths reported in 12 European countries) pointed to the need for adaptation actions, such as heat health action plans.

So what are the overall messages of this review of the literature on migration and climate change? The first is that the estimates of the number of global migrants caused by climate change are “guestimates” at best and guesses at worst. Measurement is difficult (who is a climate change refugee?) so figures are not reliable. The apparent consensus on a 200-250 million estimate is simply the result of repeating the UN figure. Based on numerous case studies, there is a sounder consensus that climate change migrants are unlikely to migrate very far because of poverty and because of mitigation through aid efforts. We judge that the numbers will not be “material” and so we will not pursue a global migration scenario. There is firmer evidence about the effect of climate change in Europe and people are much freer to move between regions and between countries. We carry out an analysis of potential European migrations linked to climate change (section 3).

2.3 Climate change scenarios linked to migration

We will focus on European internal migration. To assess the impact of climate change on migration, we need first to decide which of the IPCC (2007a) Special Reports on Emission Scenarios (SRES) best describes the future we want to investigate. This is necessary because the predicted extent of future climate change depends on the underlying assumptions which are used to run global climate models. Of the four scenario families adopted in IPCC (2001, 200a7), we reject two (A2 and B2) because of their assumptions on world population growth, a continuous increase in population over time. Recent literature on world population growth suggests an 85% probability that world population will reach its maximum before the end of the century (Lutz, 2001). The SRES scenario we will adopt is B1. This is described as follows (IPCC 2001):

> “The B1 storyline and scenario family describes a convergent world with the same global population that peaks in midcentury and declines thereafter, as in the A1 storyline, but with rapid changes in economic structures toward a service and information economy, with reductions in material intensity, and the introduction of clean and resource-efficient technologies. The emphasis is on global solutions to economic, social, and environmental sustainability, including improved equity, but without additional climate initiatives.”

To probe climate change induced migration effects in Europe, we will use downscaled climate change scenario data for Europe, which take B1 based global climate models (GCMs) as a base or downscaled GCM projections which are not emission based. We borrow heavily from the Interim Report of our sister ESPON CLIMATE project (Greiving et al. 2010), which is dedicated to investigating the impacts of climate change on territorial development, with permission from our colleagues.

2.4 An overview of European climate change

Here we briefly review the current research done on climate change impact in Europe. The key reports on Europe and Climate change we consulted were Christensen *et al.* (2007), which focuses on the regional impacts of climate change, with a special consideration of Europe in Chapter 11. Later we draw extensively on Greiving et al. (2010). Christensen et al. (2007) presents results of models which downscale from high-resolution GCMs to European level. Also part of the IPCC's 2007 fourth assessment report is Chapter 12 of IPCC (2007b) which is dedicated to Europe and discusses regional impact, adaptation and vulnerability. A recent publication of the European Environment Agency (EEA, 2008) also focuses explicitly on the impacts a changing climate will have on Europe. Figure 1 (IPCC, 2007b) gives a brief overview of the vulnerability of European regions. It is important to point out is that different European regions will be affected in very different ways, so that climate change models often distinguish between Northern Europe and the Mediterranean area (e.g. Christensen *et al.* 2007). The European region already experiences an increase in average temperature; a trend that very likely will continue in future. It is foreseen that this will lead to a more pronounced increase in summer temperature in the south of Europe and to a more pronounced increase of winter temperature in the northern parts. This will lead to more pronounced and severe droughts in Southern Europe, whereas in the more boreal parts will experience an increase in precipitation and river flooding (EEA 2008, Christensen *et al* 2007). Also because of milder winters, a reduced winter snow cover can be expected. Worldwide temperature increase and the accompanying sea level rise also might affect Europe. We anticipate the regional impacts of climate change will affect European internal migration in different ways. We propose a method for quantifying the impact of climate change on internal migration in Europe in the next section of the report.

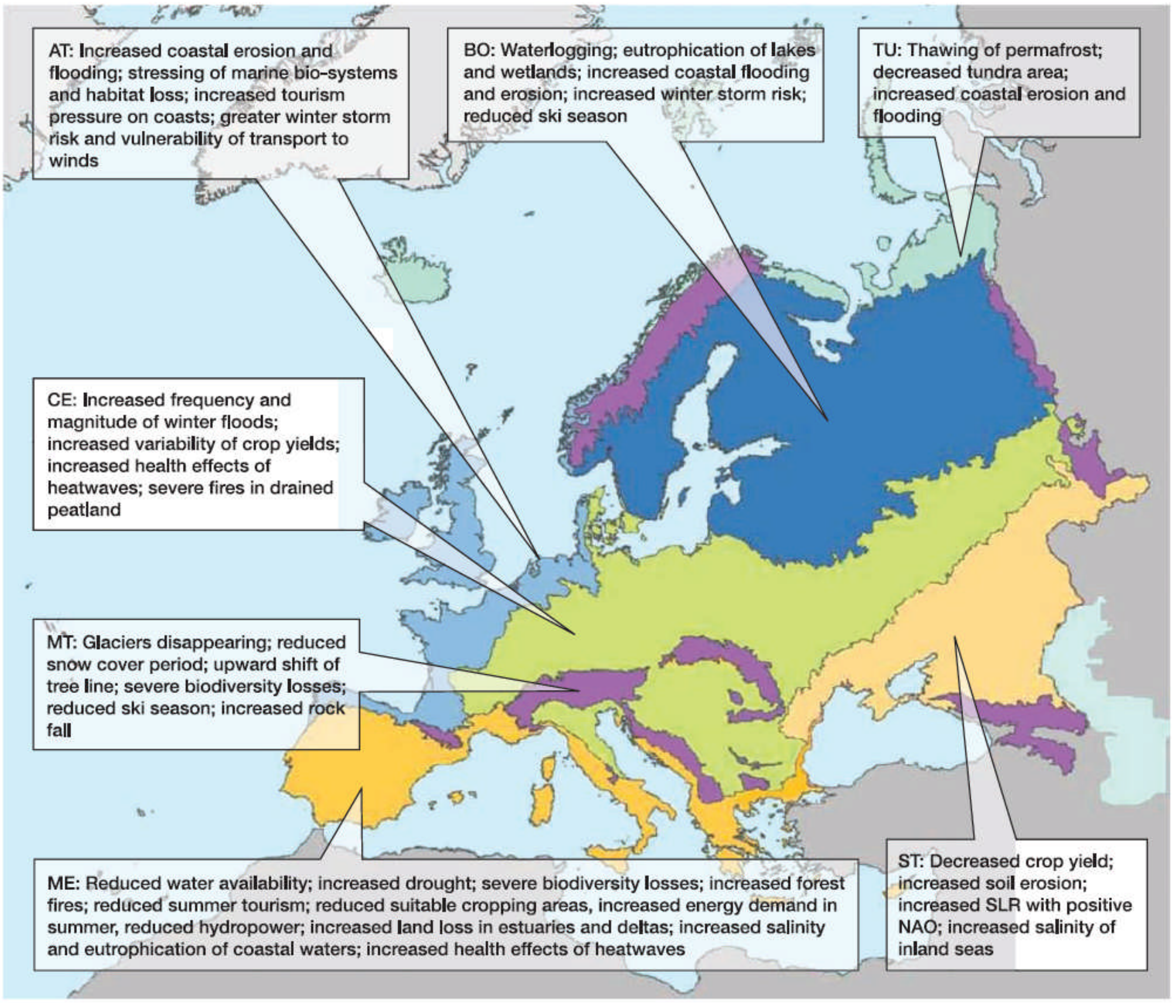

Figure 1: Key vulnerabilities of European systems and sectors to climate change during the 21st century for the main biogeographic regions of Europe

Source: IPCC (2007b), Figure 12.3 Notes: TU: Tundra, pale turquoise. BO: Boreal, dark blue. AT: Atlantic, light blue. CE: Central, green; includes the Pannonian Region. MT: Mountains, purple. ME: Mediterranean, orange; includes the Black Sea region. ST: Steppe, cream. SLR: sea-level rise. NAO: North Atlantic Oscillation.

3. METHODS FOR ASSESSING THE IMPACT OF CLIMATE CHANGE ON MIGRATION

3.1 The ESPON CLIMATE Project

To deliver the current report we collaborated with another ESPON project, ESPON CLIMATE. The analysis we present here is a broad and preliminary one. A more spatially refined analysis on the impact of climate change on the European population using the DEMIFER population projections will be completed by the ESPON CLIMATE project by the end of 2010.

So far ESPON CLIMATE has produced a set of climate change indicators (CCI) for European NUTS 3 Level regions. Eight climate change indicators are presented in maps and described in detail in the ESPON CLIMATE interim report. The CCI describe climatic changes between the periods of 1961-1990 and 2061-2100. For our current analysis, we will focus on only 5 climate change indicators considered by ESPON CLIMATE; the change in annual mean temperature, the change in winter rainfall, the change in summer rainfall and change in snow cover and heavy rainfall. In addition we will also look at sea level rise. We chose these indicators because we assume them to have a direct effect on human habitation. Each indicator and its anticipated effect on populations are presented in Table 2.

Table 2: Climate change indicators and anticipated affect on human population

Climate change indicator	Anticipated effect on humans
Increase in annual mean temperature.	Benign effects in currently cooler temperature regions Stress in regions with higher temperatures
Change in summer and/or winter rains	Decrease will lead to water stress Increase has the potential to more flooding
Decrease in annual snow cover days	Where snow cover is a recreational resource (winter sports), decrease in snow cover will reduce the ski industry
Heavy rain	Increase in heavy rainfall increases the likelihood of flooding. Flooding not only might affect living space, but also agricultural production, and with that the livelihood depending on it.
Sea level rise	Flooding & reduction of living space

To estimate the impact of climate change on migration in Europe we need to know the size of the population at risk to be affected by climate change. We assume that climate change will not lead to large numbers of climate change migrants entering Europe. Rather, current research suggests that affected populations in regions outside Europe will migrate to places nearby their origin, as people whose livelihood will be affected by climate change most likely will not have the economic means to long distance travel. For that reason we will focus on the inter-European space, more specifically we will identify the population numbers at risk which could be affected by certain climate change events.

To do this we extended population projections for the LSE scenario up to the year 2100, this Scenario is described earlier.

3.2 Methods for making the climate change and population data compatible

The DEMIFER MULTIPOLE population projections from 2050 to 2100 are produced in 5 year time steps and for NUTS2 regions. ESPON CLIMATE produced climate change indicators (CCI) for the European regions that refer to the average of the period from 2061 and 2100 and are at NUTS3 level. In a first step we averaged the projected populations (LSE scenario) over the time period from 2060 and 2100 for each of the NUTS 2 regions. The ESPON space is predicted to encounter a severe decrease in population from about 485 millions in 2060 to 406 millions in 2100. The mean population in the ESPON space is 443 millions for this period. As the data sets are for different geographical levels, they had to be made compatible. We did this in both directions: we aggregated the NUTS3 climate indicators to NUTS2 level, by averaging the NUTS3 region CCIs to NUTS2 level. These data were used to produce the cartograms with CCI data. On the other hand, we also disaggregated the NUTS2 populations into NUTS3 population by using the proportional population distribution of NUTS3 regions in each NUTS 2 regions for 2008 (downloaded from EUROSTAT). The year 2008 was chosen, as this year provided the only available data which held information for all countries. The proportional population distribution of NUTS3 regions within NUTS2 regions was assumed to be constant over time. This is a reasonable though simplistic assumption.

It is not feasible to determine the quantitative relationship between climate change variables and migration with any degree of validity. We can only assess the possible impacts of change qualitatively through proposing possible effects and possible mitigation strategies. We can assemble accounts for vulnerable regions under the different risk categories.

The ESPON CLIMATE project not only looked at single CCIs independent from each other, but also carried out a cluster analysis and identified five regions (CCR) in the European space which are characterised by similar future climate change predictions. The regions and simplified changes for the five climate change indicators we use are presented in Table 3.

Table 3: Projected changes in key climate indicators for the climate change regions of Europe

Changes in climate variables measure change between 1961-90 and 2061-2100 Populations are averaged between 2060 (higher) and 2100 (lower), using the Limited Social Europe scenario projections	**Climate change regions**						
	Not classified	Warm temperate mediterranean	Cool temperate oceanic	Cool temperate mid-continental	Cool temperate north-continental	Cold temperate and montane	
Climate change variable		Mediterranean region	Northern Western Europe	Southern Central	Northern Central	Northern Europe	Total
Change in annual mean temperature		Big rise	Rise	Big rise	Rise	Big rise	
Relative change in annual mean precipitation in winter months		Fall	Rise	Stable	Rise	Big rise	
Relative change in annual mean precipitation in summer months		Big fall	Fall	Big fall	Fall	Stable	
Change in annual mean number of days with heavy rainfall		Fall	Rise	Stable	Stable	Rise	
Change in annual number of days with snow cover		Stable	Stable	Stable	Fall	Big rise	
Population (millions)	7	108	120	132	61	17	443

Source: adapted from Greiving et al. 2010, ESPON CLIMATE Interim Report.
Notes: The columns report what will happen in each regional climate region. The top names are generic climatic zone names (this report), while the bottom names are geographical descriptions given in Greiving et al. (2010).

In the analysis that follows we present the climate indicators mentioned above for the most current period 1961-1991 in a European area map and the change of this indicator towards the end of the century (2061-2100) in a population cartogram. The maps are drawn from data ESPON CLIMATE based their calculations on, which they kindly supplied to us. The European cartogram represents each NUTS2 region by using their 2005 populations to determine the area occupied on the map. Each NUTS2 region is made up of one or more equal sized hexagons. Each hexagon represents ½ million people. For example, in 2005 the UK population was 60 millions, so that it is represented by 120 hexagons. The population of the NUTS2 region of West Yorkshire was 2.15 millions so the region is assigned 4 hexagons (2.15/0.5 rounded to the nearest integer). With this representation we highlight the area affected by a climate change variable on the one hand and the impact on the population on the other hand.

3.3 The results of the extended LSE projection

The LH in Figure 2 shows the projected total population for Europe under the LSE scenario in 5 year steps from 2005 (base year) up to 2100. The population is projected to peak in about 2030 with a population of 512 million and then declines to a final population of 406 Millions in 2100. The decline becomes very rapid from 2060 onwards. On a regional level the population change varies between region, The RH graph in Figure 2 compares the NUTS 2 regional populations in 2005 with the projected population in 2050 (red) and 2100 (green). The black line is the line of equality when projected values are equal to the original values. Although the scatter indicates significant re-distribution of the population across Europe's regions (described in Deliverable D7), the correlation is close enough not to invalidate the use of a population cartogram based on the 2005 population.

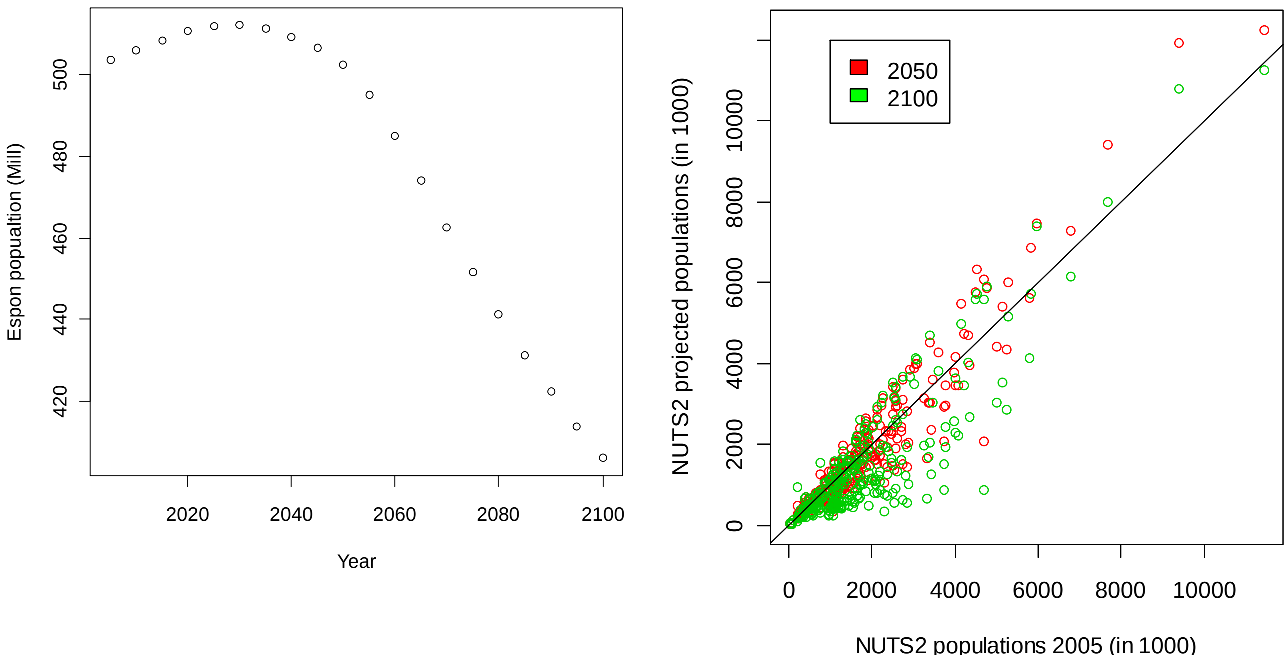

Figure 2: Total population in the ESPON space as projected by the extended LSE scenario from 2005 to 2100 and a scatter plot of projected populations in 2005, 2050 and 2010 for NUTS regions

We calculated how many people will live in each country on average between 2060 and 2100 in each of the climate change regions (Table 4) and summarised these figures for the climate change regions (Table 5). For an average of 7 million people (1.5 %) of the ESPON population no information on the CCR is available. These are overseas territories. Only 3.8 % of the ESPON population will live in Northern Europe, whereas more than 50% of the population is predicted to live in the Southern Central Europe and the Mediterranean. This means over half of the ESPON population will be affected by a considerable decrease in summer rains and an increase in mean annual temperature to an extent that livelihood could be affected.

Table 4: Population by country and climate regions, total numbers and percent of population

	Population in 1000s (2060-2100 average)							Percent of country population					
Country	None	Southern Central	Northern Europe	Northern Central	Mediterranean region	Northern Western Europe	Total	None	Southern Central	Northern Europe	Northern Central	Mediterranean region	Northern Western Europe
AT	0	5,900	1,054	676	0	0	7,629	*0*	*77*	*14*	*9*	*0*	*0*
BE	0	4,733	0	399	0	5,368	10,500	*0*	*45*	*0*	*4*	*0*	*51*
BG	0	2,166	0	0	1231	0	3,397	*0*	*64*	*0*	*0*	*36*	*0*
CH	0	5,575	799	0	0	0	6,374	*0*	*87*	*13*	*0*	*0*	*0*
CY	0	0	0	0	335	0	335	*0*	*0*	*0*	*0*	*100*	*0*
CZ	0	1,725	0	4,214	0	0	5,940	*0*	*29*	*0*	*71*	*0*	*0*
DE	0	28,249	94	17,701	0	8,143	54,188	*0*	*52*	*0*	*33*	*0*	*15*
DK	0	0	0	4,875	0	0	4,875	*0*	*0*	*0*	*100*	*0*	*0*
EE	0	0	638	87	0	0	725	*0*	*0*	*88*	*12*	*0*	*0*
ES	2,195	2,867	0	0	39,011	0	44,072	*5*	*7*	*0*	*0*	*89*	*0*
FI	0	0	5,132	50	0	0	5,183	*0*	*0*	*99*	*1*	*0*	*0*
FR	3,295	4,2647	501	0	13,396	12,654	72,493	*5*	*59*	*1*	*0*	*18*	*17*
GR	217	91	0	0	7,904	122	8,334	*3*	*1*	*0*	*0*	*95*	*1*
HU	0	5,896	0	0	0	0	5,896	*0*	*100*	*0*	*0*	*0*	*0*
IE	0	0	0	0	0	5,159	5,159	*0*	*0*	*0*	*0*	*0*	*100*
IS	272	0	0	0	0	0	272	*100*	*0*	*0*	*0*	*0*	*0*
IT	0	19,383	868	0	37,981	0	58,232	*0*	*33*	*1*	*0*	*65*	*0*
LI	0	17	0	0	0	0	17	*0*	*100*	*0*	*0*	*0*	*0*
LT	0	0	501	1150	0	0	1,651	*0*	*0*	*30*	*70*	*0*	*0*
LU	0	411	0	0	0	0	411	*0*	*100*	*0*	*0*	*0*	*0*
LV	0	0	269	773	0	0	1,042	*0*	*0*	*26*	*74*	*0*	*0*
MT	239	0	0	0	0	0	239	*100*	*0*	*0*	*0*	*0*	*0*
NL	0	421	0	0	0	14,632	15,052	*0*	*3*	*0*	*0*	*0*	*97*
NO	0	0	4,701	235	0	0	4,936	*0*	*0*	*95*	*5*	*0*	*0*
PL	0	0	0	21,388	0	0	21,388	*0*	*0*	*0*	*100*	*0*	*0*
PT	404	182	0	0	7,403	0	7,989	*5*	*2*	*0*	*0*	*93*	*0*
RO	0	7,980	0	0	204	0	8,184	*0*	*98*	*0*	*0*	*2*	*0*
SE	0	0	2,288	7,717	0	0	10,005	*0*	*0*	*23*	*77*	*0*	*0*
SI	0	1,214	0	0	0	0	1,214	*0*	*100*	*0*	*0*	*0*	*0*
SK	0	2,141	0	866	0	0	3,006	*0*	*71*	*0*	*29*	*0*	*0*
UK	20	0	0	676	0	73,717	74,413	*0*	*0*	*0*	*1*	*0*	*99*

Source: authors' computations

Notes: AT = Austria, BE =Belgium, BG = Bulgaria, CH = Switzerland, CY = Cyprus, CZ = Czech Republic, DE = Germany, DK = Denmark, EE = Estonia, ES = Spain, FI = Finland, FR = France, GR = Greece, HU = Hungary, IE = Ireland, IS = Iceland, IT = Italy, LI = Liechtenstein, LT = Lithuania, LU = Luxembourg, LV = Latvia, MT = Malta, NL = Netherlands, NO = Norway, PL = Poland, PT = Portugal, RO = Romania, SE = Sweden, SI = Slovenia, SK = Slovakia, UK = United Kingdom

Table 5: Average population (in millions) and percent of population in ESPON space in each of the climate change regions

Climate change regions	Climate change regions according to ESPON CLIMATE/Greiving et al 2010)	Average population in 2060-2100	% of total ESPON population
No information	None	7	1.5
Southern Central	Cool temperate, mid-continental	132	29.7
Northern Europe	Cold temperate and montane	17	3.8
Northern Central	Cool temperate, north-continental	61	13.7
Mediterranean region	Warm temperate, Mediterranean	107	24.3
Northern Western Europe	Cool temperate, littoral	120	27.0
Total		443	100.0

We quantify in detail the population numbers affected by the most extreme of each climate change variable. We define as extreme the uppermost or lowermost class (as appropriate) in each of the climate change variable. We calculate the population number in each region and for each indicator. Numbers are presented in Table 6. For example, we consider extreme temperature change as an increase of mean annual temperature of more than 4 °C. Some 19.91 million people in the Warm temperate, mediterranean region live in areas where the mean annual temperature is predicted to increase by more than 4 °C from 1961-1991 to 2061-2100. These make up 18.6% of the total population in this area.

Table 6: Total population in millions and percentage population of each climate change region affected by extreme climate change by 2061-2100

Climate change variable change	Warm temperate, mediterranean	Cool temperate, mid-continental	Cool temperat e, littoral	Cold temperate and montane	Cool temperate, north-continental	All regions
	Total population in millions (Percent of population in cluster/zone)					
Temperature increase > 4 °C	19.91 (18.6)	16.70 (12.6)	0.00 (0.0)	2.67 (15.7)	0.00 (0.0)	39.28 (8.9)
Winter precipitation decreases > 20%	33.08 (30.9)	0.59 (0.4)	0.12 (0.1)	0.00 (0.0)	0.00 (0.0)	33.79 (7.6)
Summer precipitation decreases > 40%	82.50 (77.1)	45.19 (34.2)	3.78 (3.1)	1.00 (5.9)	0.00 (0.0)	132.47 (29.9)
Days of heavy rain (20mm +) increase >7	0.00 (0.0)	0.00 (0.0)	0.00 (0.0)	1.03 (6.1)	0.00 (0.0)	1.03 (0.2)
Days of snow cover decrease >51	0.00 (0.0)	2.78 (2.1)	0.00 (0.0)	14.01 (82.4)	0.07 (0.1)	16.85 (3.8)

4. ANALYSIS OF THE IMPACT OF CLIMATE CHANGE ON MIGRATION

4.1 Temperature changes and their effects

Table 3 revealed a strong increase in the annual mean temperatures in three regions, Northern Europe, Southern Europe and the Mediterranean region (also shown in Figure 4). The temperature change will affect the environment in each of these regions considerably in terms of vegetation change and water availability. As for the effect on human population livelihood we assume that an increase in temperature will have a more severe affect in Southern Europe and the Mediterranean regions, as the temperatures increase from a higher base value (Figure 3), and will lead to higher temperatures in the rest of this century. The expected mean temperatures in Northern Europe are far lower and will affect everyday lives less.

The mean annual temperature varied considerably across Europe in the period 1961-1990. In the most northern countries the mean annual temperature was below 5°C. Mean annual temperatures between 10 to 15°C and over were observed in the more Southern regions (Figure 3). Mean temperature is predicted to increase across Europe (Figure 4). However, the resulting mean annual temperatures still will vary considerably. Even though temperature changes of more than 3.5°C are predicted for Finland as well as for parts of Spain and Italy, mean annual temperatures in Finland will reach status quo central European conditions, whereas Southern Europe might exceed 20°C, a temperature comparable to sub-tropical to tropical conditions

In the whole ESPON space, 39.3 million people live in areas where mean annual temperature is predicted to increase by more than 4 °C. This represents about 9% of the total ESPON population. A much higher population percentage of the warm temperate, mediterranean region is affected by extreme temperature increase compared to the average across the ESPON space. Note that the population cartogram (Figure 4) shows that large metropolitan regions (Madrid, Marseille, Milano) are particularly affected because they experience the urban heat island condition, in which the concentration of built up area absorbs more solar radiation and maintains higher night-time temperatures than the countryside. In addition, the temperature increase in this region can be classified as temperature stress (Table 3 and Figure 1).

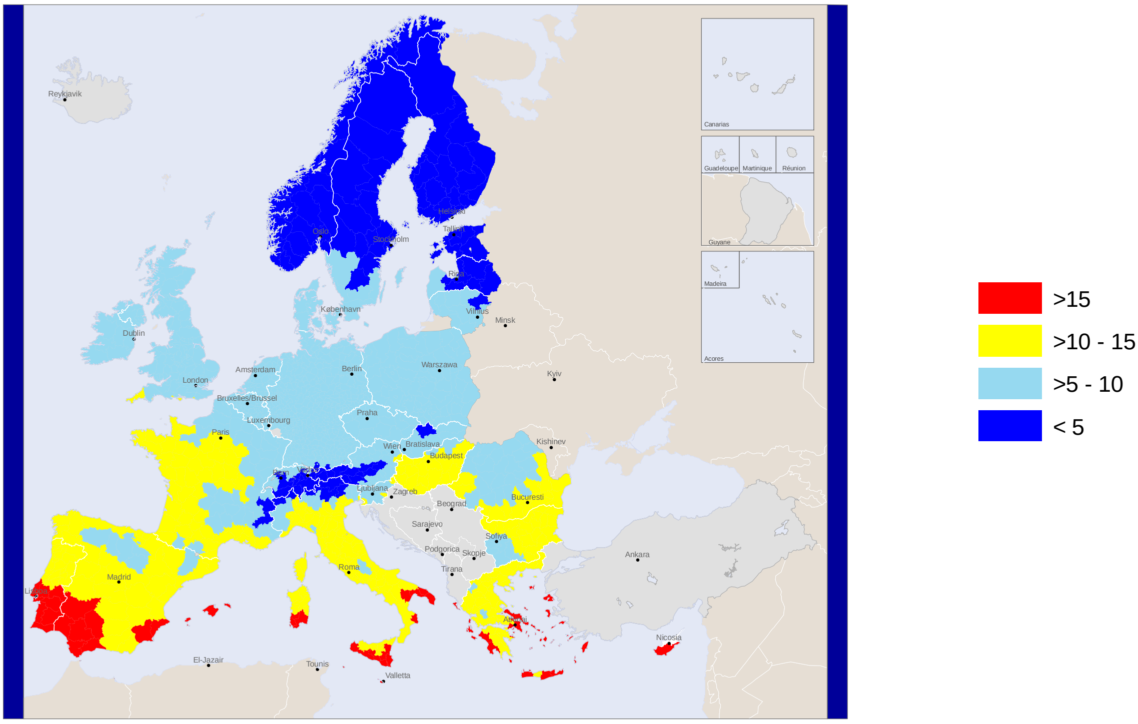

Figure 3: Mean annual temperature ℃ during the period 1961/1990, NUTS 3 regions.
Source: ESPON CLIMATE, personal communication

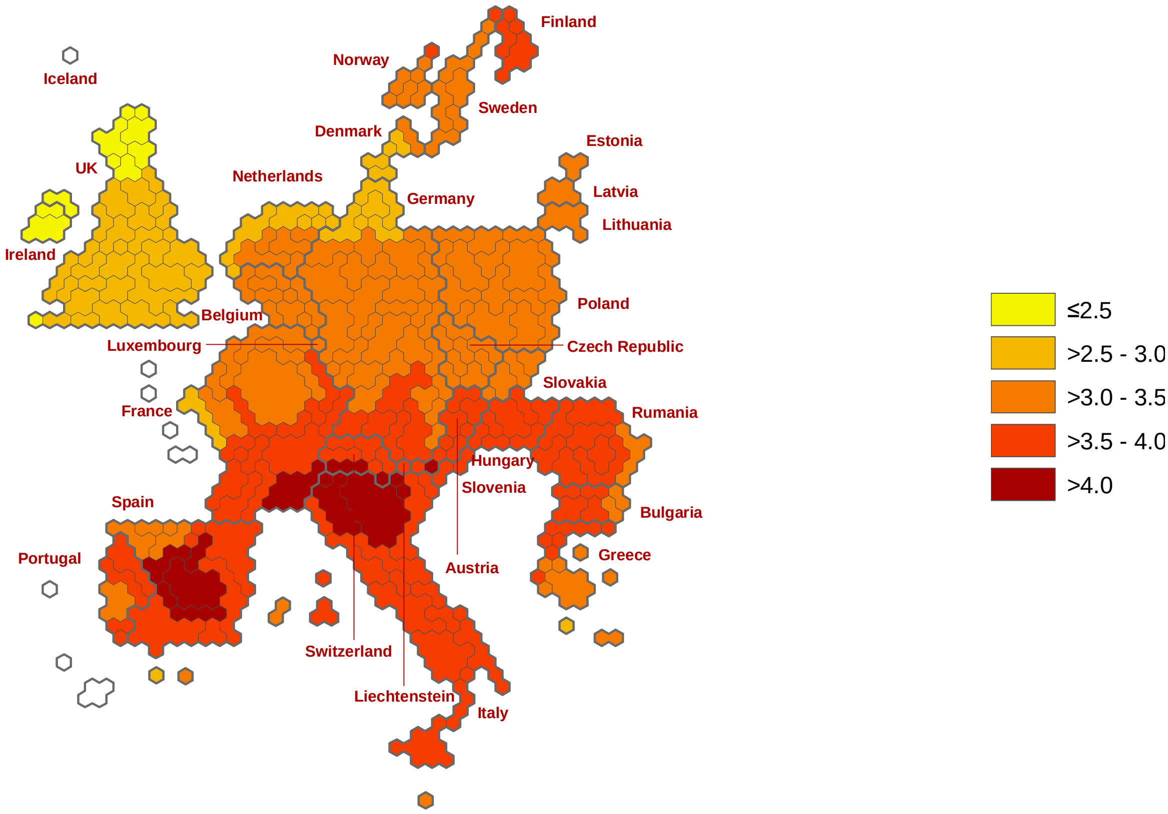

Figure 4: Change in mean annual temperature (°C) between 1961/1990 and 2061/2100
Source: Climate statistics adapted from Greiving et al. (2010). Authors' cartogram.

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4.2 Winter precipitation changes and their effects

We examine mean winter precipitation because this indicator is important in regions with high summer water deficits (resulting from a combination of low summer rainfall and high evapo-transpiration). Winter rains and snows provide water for storage in aquifers and reservoirs for use in summer agriculture and for industrial and domestic use in the summer months. Mean winter precipitation is higher in many parts of Southern Europe (northern Iberia, much of France) compared to Northern and Eastern Europe (Figure 5), though the higher evapo-transpiration removes much of this advantage. For Southern Europe it is predicted that the already drier parts will suffer water crises. For example, coastal cities in southern Spain already need to buy water from other regions and to invest in energy-intensive desalination plants. The change map (Figure 6) shows highest decreases in winter precipitation in the provinces of Andalucia, Murcia, Valencia, the Balearic Islands, Sardinia, Sicilia, Calabria and most of Greece. These regions house 18.6% of the populations of the Warm temperate, Mediterranean zone (Table 6) and receive large tourist flows in all seasons as well. We comment on the likely impact in section 4.7.

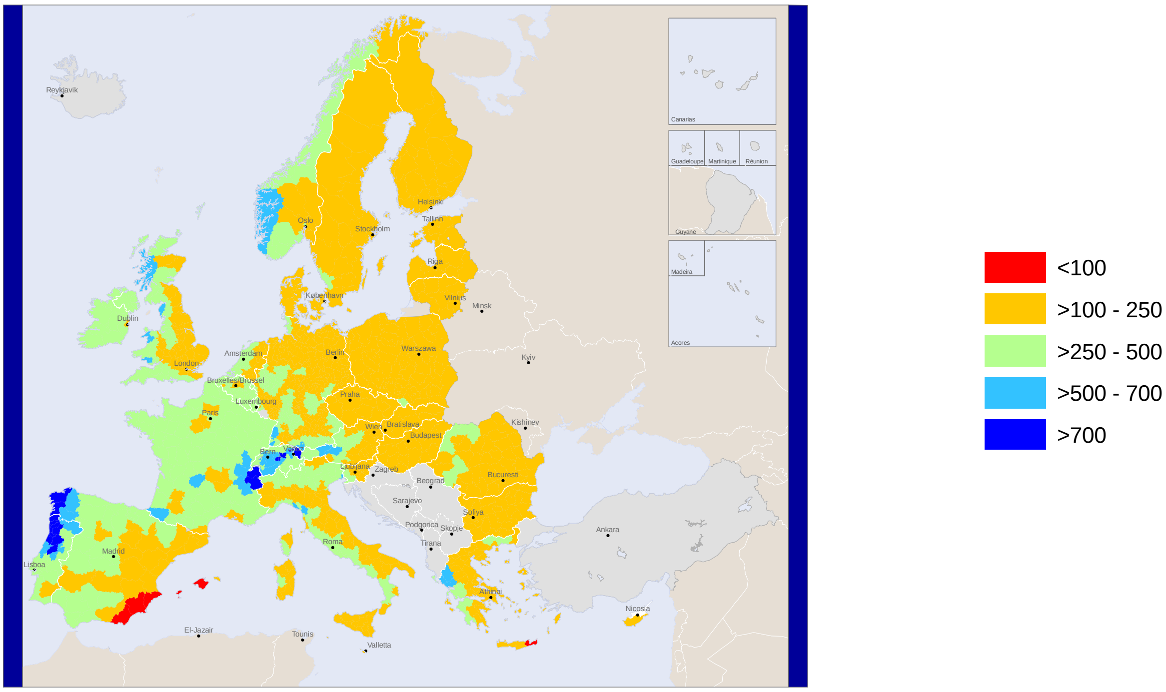


Figure 5: Mean precipitation (mm) in winter during the period 1961-1990, NUTS 3 regions
Source: ESPON CLIMATE, personal communication.

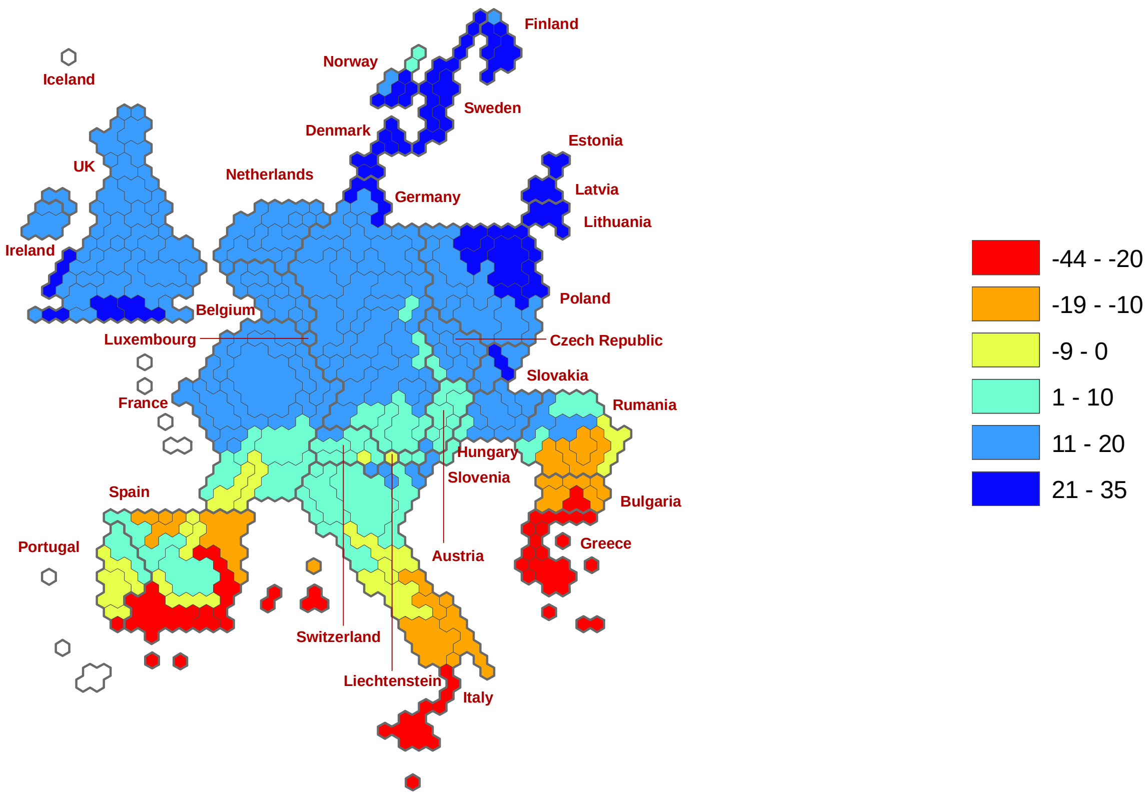


Figure 6: Change in annual mean winter precipitation in % between 1961-1990 and 2061-2100
Source: Climate statistics adapted from Greiving et al. (2010). Authors' cartogram.

4.3 Summer precipitation changes and their effects

Summer precipitation is also predicted to decrease in southern belts of Europe, reducing precipitation by over 40% (compare Figures 7 and 8). To a certain extent activities in these regions are already adapted to severe summer water deficits in terms of plant communities and farming practices. Irrigation is widely practised but the efficiency of water use will need to improve radically through use of techniques such as poly-tunnels to recycle evapo-transpirated water, drip feed irrigation delivering water to exactly where it is needed and use of drought tolerant plant species. New sources of water will be needed: the nearest is the sea through desalination. This is an energy intensive process but the energy source will be available through increased solar radiation and thermal solar power plants, already in operation in southern Spain.

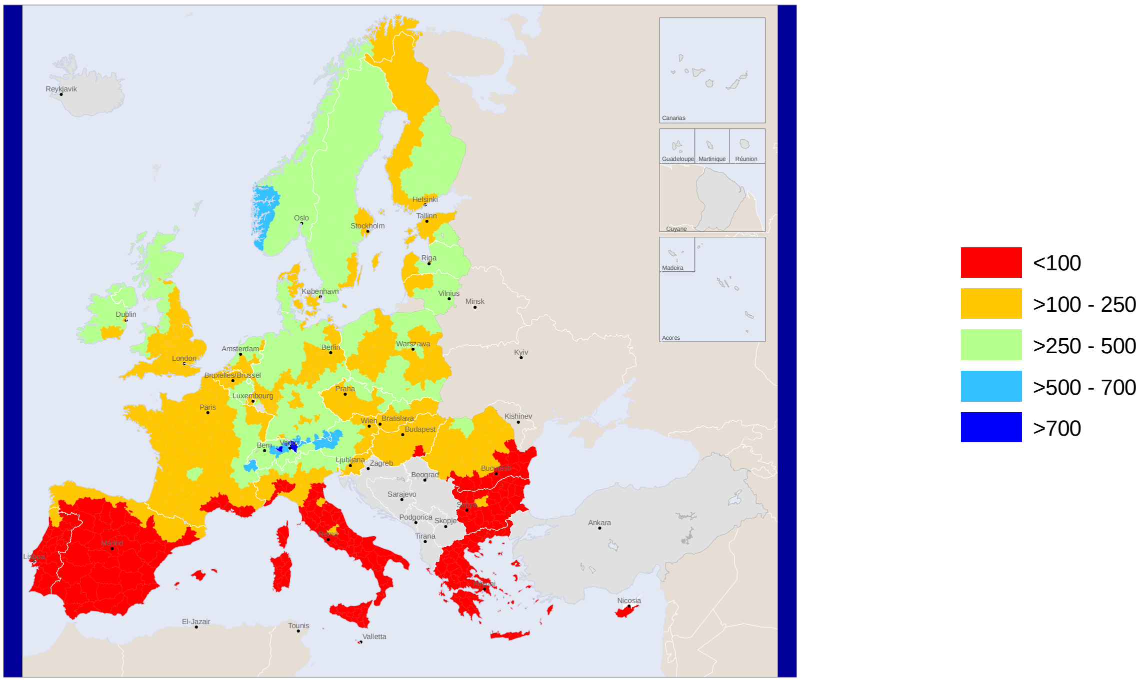


Figure 7: Mean precipitation (mm) in summer during the period 1961/1990, NUTS 3 regions
Source: ESPON CLIMATE, personal communication

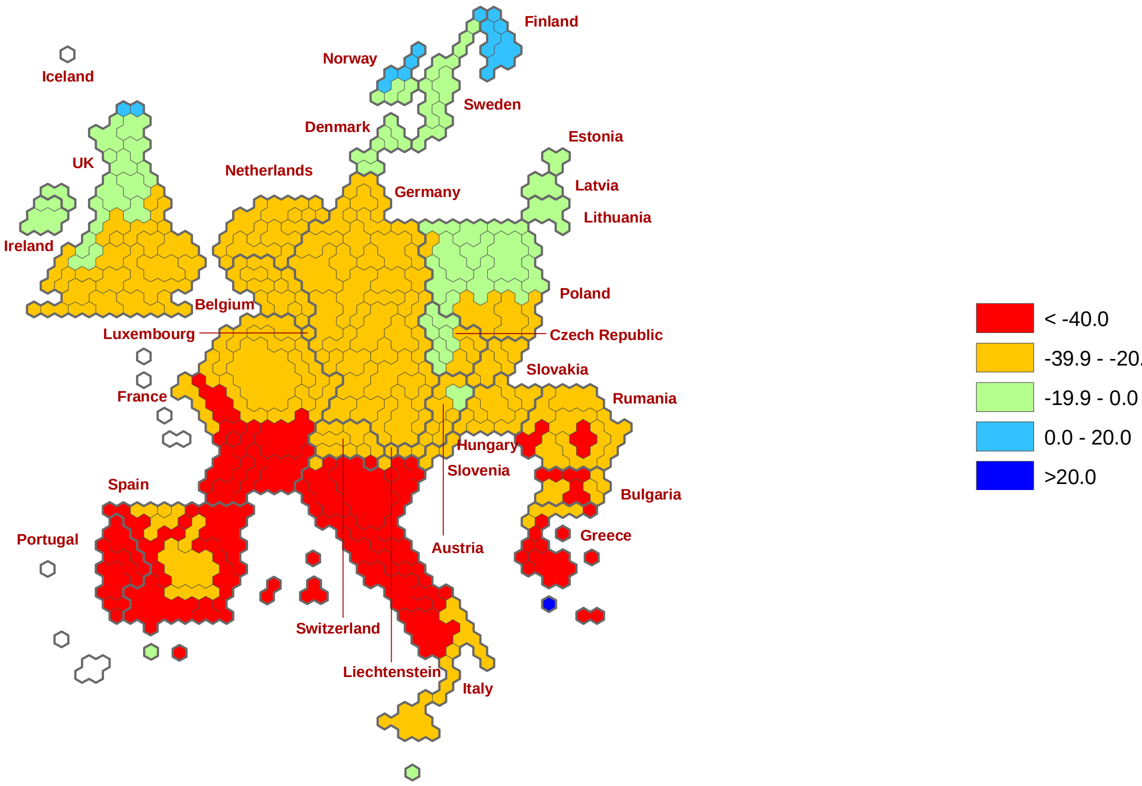


Figure 8. Change in annual mean summer precipitation in % between 1961-1990 and 2061-2100
Source: Climate statistics adapted from Greiving et al. (2010). Authors' cartogram.

4.4 Heavy rainfall changes and their effects

From the map of conditions in the period 1961-1990 (Figure 9) we can see that days of heavy rain are a phenomenon of exposed Atlantic coasts such as Galicia in Spain, the North West Highlands and Islands of Scotland, the fjord coast of Norway, Alpine regions in France, Switzerland and Austria and some areas along the western coasts of Italy and Greece. The highest change in the annual number of days with heavy rainfall will be experienced in western Scotland and south western Norway (Figure 10). This may cause some local floods such as those that occurred in Cumbria in Northwest England in November 2009. The small town of Cockermouth was flooded and the bridges across the River Derwent, which connected two parts of the town of Workington, were destroyed. However, the speed of the response to the environmental crisis was impressive (BBC 2009b):

> A Cumbrian town divided when floods destroyed its river crossings, killing a police officer, has been re-united by a temporary footbridge. Workington's Barker Crossing, built by the Army, is named after Pc Bill Barker who died when Northside Bridge was washed away during last month's floods. The 170ft (52m) bridge across the River Derwent took a week to build.

The increased heavy rainfall may contribute to increased hydro-power and to the viability of pumped storage hydro, needed to store night time surplus wind power.

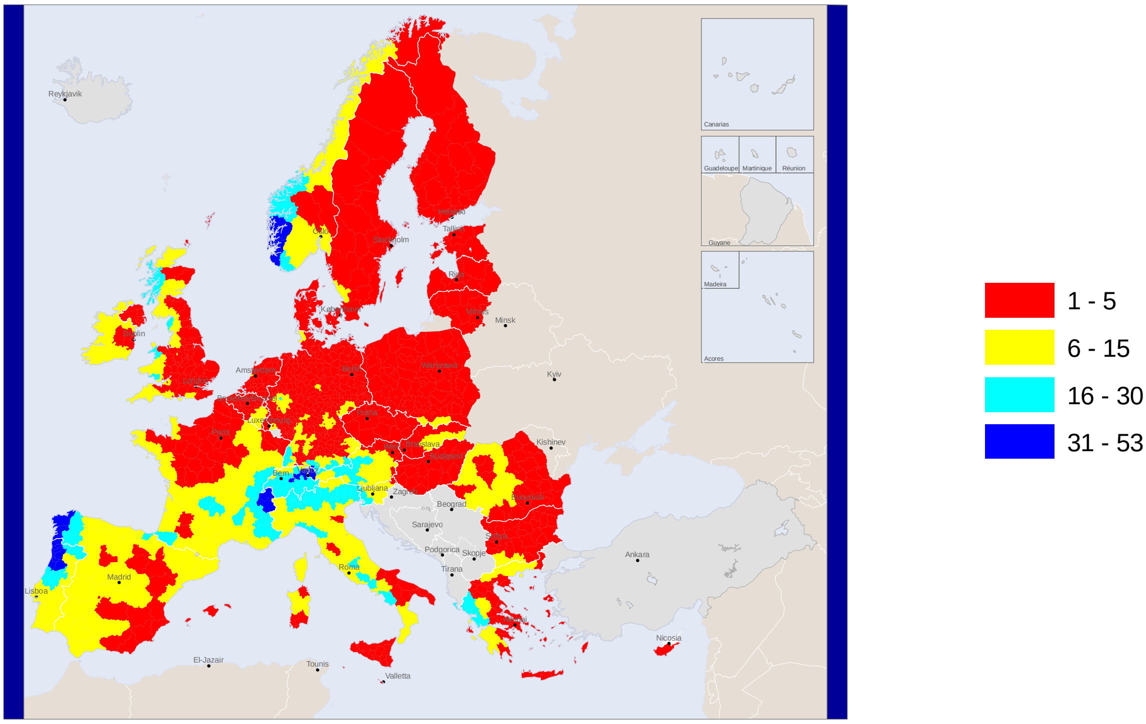


Figure 9: Number of days with heavy rainfall in a year (>20mm) during the period 1961-1990, NUTS 3 regions.
Source: ESPON CLIMATE, personal communication.

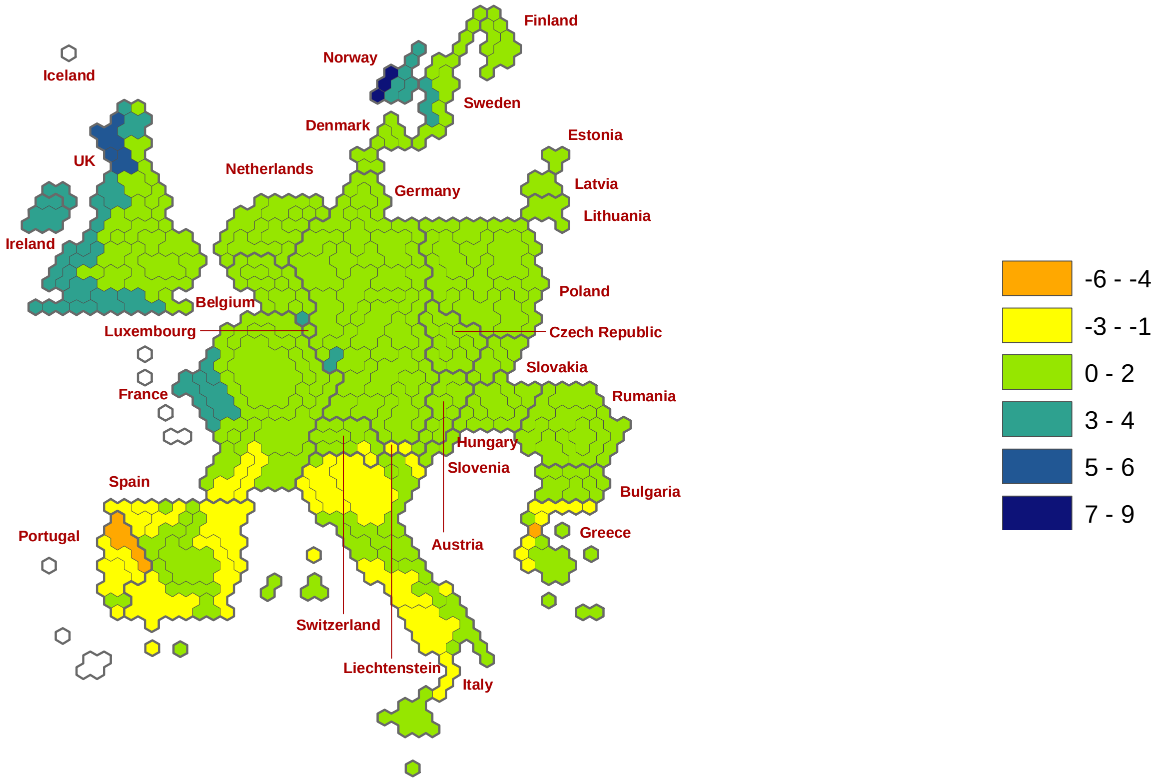


Figure 10: Change in annual numbers of days with heavy rainfall between 1961-1990 and 2061-2100
Source: Climate statistics adapted from Greiving et al. (2010). Authors' cartogram.

4.5 Snow cover changes and their effects

Figure 11 presents information on average annual days with snow cover in the 1961-1990 period derived from the work of the ESPON CLIMATE project. We are a little sceptical about the zero days category, though we may have misunderstood the definition of the variable. Areas with many days of snow cover are found in the Nordic regions, in the Alpine regions, in the Baltic republics, in the Carpathian mountains (Romania) and in the Tatra mountains (Poland and Slovakia). All of these areas will experience quite considerable declines in snow cover. The main impacts will be on the winter sports industry which will need to adapt (see section 4.7). On the other hand the residents of the largest cities in the affected regions will be spared some of the expense and labour of snow clearance.

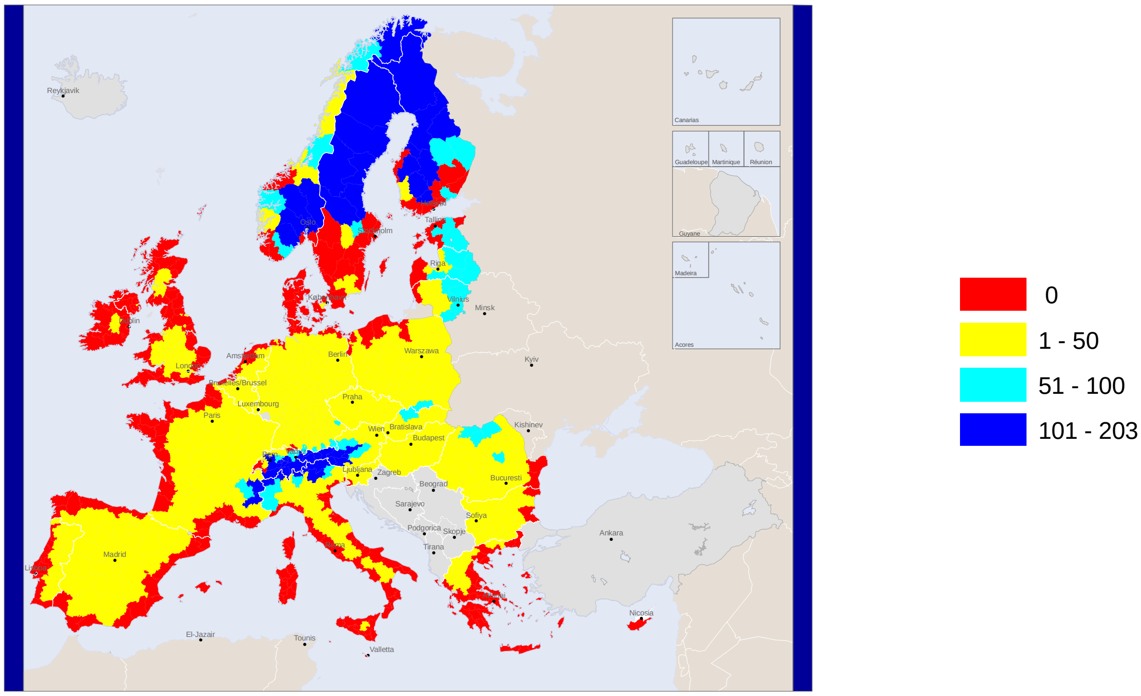


Figure 11: Annual days with snow cover during the period 1961-1990, NUTS 3 regions
Source: ESPON CLIMATE, personal communication). Note: Possible error in the red areas.

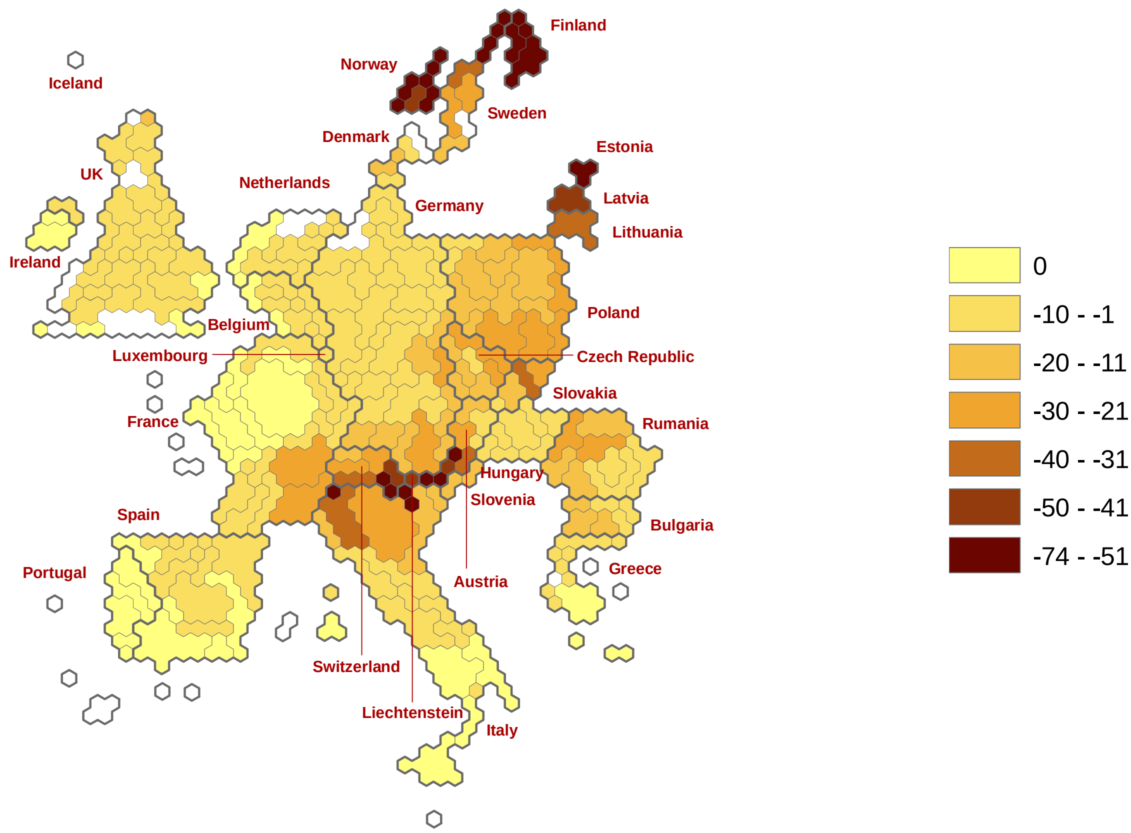


Figure 12: Change in annual mean number of days with snow cover between 1961-1990 and 2061-2100
Source: Climate statistics adapted from Greiving et al. (2010). Authors' cartogram.

4.6 Sea level rise and its effects

Figure 13 identifies areas which would be affected by a sea level rise of one metre. The areas are identified in red and are found around the coasts of northern Europe, particularly the North Sea and the Netherlands. Will this cause population displacement? We think it unlikely except as a slow planned process of retreat where the coastal infrastructure is of low value. Where this infrastructure is of high value, mitigation measures will be taken. The Netherlands, for example, has a long history of engineering barriers to keep out both river and sea flood waters. Nearly 25% of the country is already below sea level. On the other hand the UK Environment Agency plans to protect only the most valuable part of the UK's North Sea coast (the Thames Estuary and London) and to let the processes of wave erosion and sea flooding work through, learning from the experience of King Canute. Figure 13 is only an example of potential sea level rise. Sea level today in Europe is rising by between 0.8 mm to 3 mm per annum and is predicted to rise up by only 0.3 m by the end of the century under the B1 Climate Change scenario. However, on certain coasts such as those of South East England and additional process of land tilting is taking place as the United Kingdom experiences isostatic uplift consequent on the retreat of the ice sheets of the last glaciations. This uplift raises northwest Scotland but depresses south east England.

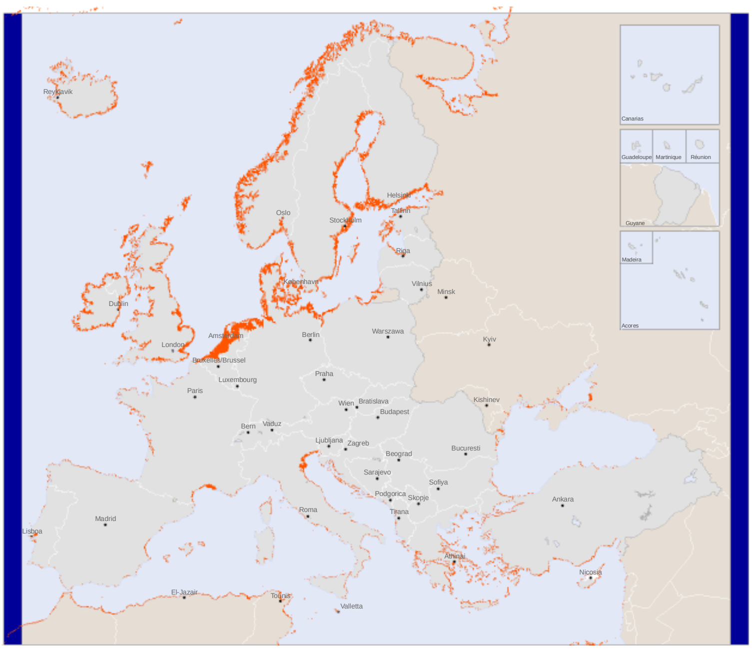
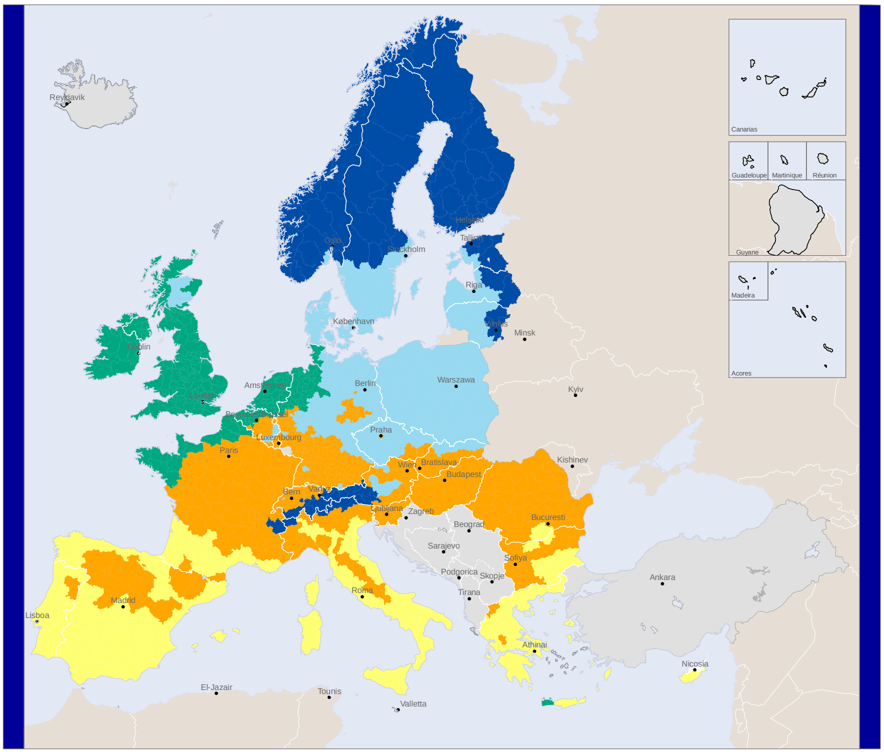


Figure 13: Sea level rise projected by 2100
Source: CReSIS, Centre for Remote Sensing of Ice Shields (2010)
Notes: The extent of a one metre sea level rise (orange) in Europe.

4.7 Impacts for the climate regions

To assess the impact of climate change on migration within Europe, we adopted the clusters of regions defined by the ESPON CLIMATE (Greiving *et al.* 2010). This provides us the means of bringing together the systematic results presented earlier in section 4 for a small set of climate change regions. We have altered the descriptions from "regional" to "climatic" (Figure 14 and Table 5) because the geographical descriptions did not apply to several regions (e.g. the Alpine regions were labelled "Northern Europe"). Selected climate change variables were available at NUTS3 scale in Greiving et al. (2010) and we averaged them for NUTS2 regions in order to determine what populations in 2060-2100 fell within each category of climate change. The country level changes are set out in Table 4 and the broad changes predicted are set out in Table 5, discussed earlier in the report. We discuss the climate change regions in order hotter to colder.



Dark blue	Cold temperate and montane
Light blue	Cool temperate north continental
Green	Cool temperate oceanic
Orange	Cool temperate mid-continental
Yellow	Warm temperate mediterranean

Figure 14: The five climate regions identified by ESPON CLIMATE, named according to their climate regime
Source: Greiving et al. (2010)
Notes: Only regions for which DEMIFER produces population data and ESPON CLIMATE change variables are coloured in this map.

In the **Warm temperate mediterranean climate zone**, big rises are projected in mean annual temperature and big falls in summer rainfall. The rise in temperature will be substantial (Figure 4), more than 3.6 degrees Celsius in most regions and more than 4 degrees Celsius in the major metropolitan areas (Madrid, Marseille, Milan, Rome, Naples). There will be a big fall in summer rainfall which will cause difficulties for agriculture and horticulture, while the fall in winter precipitation will lead to problems in storing enough water for summer demand. In this climatic zone will reside, on average between 2060 and 2100, 108 million people. In the Warm temperate Mediterranean climate zone, the hotter climate may well encourage some return migration by retirees from northern Europe. There may also be reduced in-migration from northern Europe of retirees.

However, there is evidence that richer people are able to adapt to hot climatic conditions through seasonal migration (wintering in the south, summering in the north). The difficulties of climate change in this zone will be experienced by those unable to adopt a seasonal circulation. Water shortages are already experienced in Mediterranean regions and schemes for transferring water by pipeline or ship from wetter areas are already in place. There is one obvious water source that is easily accessible, the sea and the energy can be supplied by the development of solar power (boiling fluid plants using solar mirrors). Spain is already a pioneer in developing such technology. Our opinion is that regions will mitigate the consequences of climate change in these ways and people will adapt through multi-locational life styles. During the British imperial occupation of India, for example, the government in New Delhi would relocate to Simla in the Himalayas during the hot season. But the most obvious but energy expensive mitigation will be the adoption of air-conditioning by households. The additional energy should come from renewable resources rather than hydrocarbons.

In the **Cool temperate oceanic climate zone**, the climate changes are relatively subdued because of the oceanic circulation. There will be challenges from lower summer rainfall and greater storminess in winter but these changes will be balanced by the extension of the growing season and the additional productivity of agriculture. This zone is densely populated and will house an average of 120 million people in the 2060-2100 decades. The greatest challenge will be along the coastal regions vulnerable to the rise in sea level. We have already discussed the likely responses, drawing on examples from the Netherlands and the United Kingdom.

In the **Cool temperate mid-continental climate zone**, there will be changes similar to those in the Warm temperate mediterranean zone though they will be a little less extreme. Figure 4 shows mean annual temperature will rise by 3.1 to 4.0 degrees, less in the west and more in the east. Summer rainfall will show a big fall. This climatic zone is inhabited by 132 million people. These changes are unlikely to cause streams of out-migration but the temperature changes may encourage seasonal movements to higher elevations, which are accessible from this zone. These areas are in the Alps, the Carpathians, the mountains bordering the Czech Republic and Slovakia and the upland areas of France such as the Massif Central.

In the **Cool temperate north continental climate zone,** climate changes are important but not catastrophic. For farming they may be favourable, providing the summer water deficits can be met through suitable storage, transfer and careful use. We do not anticipate any substantial migration out of this region in addition to that already taking place for economic reasons. The population that is likely to be resident in this zone is only 61 millions and declining, so that water demand will be reducing.

In the **Cold temperate and montane climate zone,** there are big changes anticipated but these will affect a relatively small population of 17 million. Although the geographical area covered by this zone is large (Figure 14), the regional populations are small and live at low densities as indicated by the shrunken footprint of the Nordic countries in Figure 4. Mean annual temperature does rise considerably in this zone and may have impacts on the natural environment. The demographic impact will be slight. However, the change in annual number of days with snow cover will have serious impact on winter resort settlements. Mitigation measures already being used include the development of higher *pistes*, the generation of artificial snow and the development of summer tourism to cater for city dwellers at lower altitudes fleeing the summer heart.

5. DISCUSSION AND CONCLUSIONS

In this report we have explored the likely impacts of climate change on migration. The literature is highly speculative with lots of interesting case studies but rather less in the way of reliable statistics on past migration linked to climate change. There are understandable reasons why this should be the case. Our review of the literature revealed poor definitions of what constituted a climate change migrant and the methods used to identify the numbers hardly robust. Guestimates of millions of additional displaced persons were re-quoted in study after study. Extreme climate events, such as the September 2010 floods in the Indus catchment in Pakistan, can cause massive temporary displacement. But case studies, based on firmer field evidence, show that this displacement is quite local in scale and that as many displaced persons try to return to their former homes as possible. The floodwaters recede enabling farmers to re-occupy their land. So our judgement was that it is not possible to estimate the small number of additional migrants who will come to Europe against a background flow of millions of other kinds of migrant.

However, it was worth finding out whether the impact of climate change is likely to be small or large by integrating a climate factors analysis with one of our policy scenarios. To measure the degree of climate change in the future, we borrowed results from ESPON CLIMATE (IPCC Scenario B1) and extended one of our policy scenarios from 2050 to 2100. We could then identify the future populations living in climate regions of highest change. We systematically analysed six climate change indicators, comparing the situation in 1961-1990 with that in 2060-2100, plotting change on a population cartogram that shows more accurately the sizes of the populations that may be affected. We then brought together the results for the six individual variables for each of five climate change zones and discussed both the changes and the adaptive actions and mitigations that were likely.

Much of the analysis of the impact of climate change is a matter of judgement. Our judgement is that the likely migration impact will be slight noise against a background of much bigger flows that we have already included in our scenario projections. We have argued that countries, regions, businesses and households will invest in mitigation measures and will adapt to the climate change envisaged, as past experience suggests. However, careful planning of the adaptive strategies will be needed. Societies that think long term are those most likely to prosper.

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