ESPON

ESPON Climate

Climate Change and Territorial Effects on Regions and Local Economies

Applied Research 2013/1/4

Draft Final Report | Version 25/2/2011

Summary Report

EUROPEAN UNION
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This report presents the draft final results of an Applied Research Project conducted within the framework of the ESPON 2013 Programme, partly financed by the European Regional Development Fund.

The partnership behind the ESPON Programme consists of the EU Commission and the Member States of the EU27, plus Iceland, Liechtenstein, Norway and Switzerland. Each partner is represented in the ESPON Monitoring Committee.

Information on the ESPON Programme and projects can be found on www.espon.eu

The web site provides the possibility to download and examine the most recent documents produced by finalised and ongoing ESPON projects.

This basic report exists only in an electronic version.

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1. Introduction

Territorial development is generally considered as very important for dealing with climate change. For instance, territorial development is regarded to be responsible for and capable of reducing regional vulnerability to climate change and developing climate mitigation and adaptation capacities against the impacts of climate change (Stern, 2006; IPCC, 2007c). Also, the World Bank Report „The Global Monitoring Report 2008“ which deals with climate change and the Millennium Development Goals concludes that the development of adaptive urban development strategies is a fundamental field of action for dealing with the challenges of climate change (World Bank, 2008).

The EU White Paper „Adapting to climate change: Towards a European framework for action" (European Commission, 2009a, 4) explicitly relates to spatial planning and territorial development, respectively: „A more strategic and long-term approach to spatial planning will be necessary, both on land and on marine areas, including in transport, regional development, industry, tourism and energy policies."

In the EU Territorial Agenda (BMVBS, 2007a, 7) it is stipulated under Priority 5 that "joint transregional and integrated approaches and strategies should be further developed in order to face natural hazards, reduce and mitigate greenhouse gas emissions and adapt to climate change. Further work is required to develop and intensify territorial cohesion policy, particularly with respect to the consequences of territorially differentiated adaptation strategies."

Mickwitz et al. (2009, 60) came to the following conclusion: „While the need for co-ordination and integration across sectors, scales and levels is growing, the capacities to respond are frequently shrinking […]. While it is generally recognised that the role of spatial planning for climate mitigation and adaptation should be strengthened, the practice is not very well developed as yet." Thus, there is a need for a step forward towards a clear territorial response to climate change.

However, territorially differentiated adaptation strategies call for an evidence basis. This is what the ESPON Climate project is mainly about; a pan-European vulnerability assessment as a basis for identifying regional typologies of climate change exposure, sensitivity, impact and vulnerability. On this basis, tailor-made adaptation options can be derived which are able to cope with regionally specific patterns of climate change. In the ESPON Climate project this regional specificity is addressed by seven case studies from the transnational to the very local level.

ESPON Climate's territorial perspective is somehow unique, because most of the existing vulnerability studies have a clear sectoral focus, addressing very specific potential impacts of climate change on single elements of a particular sector. The leading existing studies have so far not employed such a comprehensive methodological approach. Furthermore, most studies lack a clear territorial pan-European focus. Specialised research is sensible and necessary but the findings of specialised studies are not easily transferable between sectors or between regions. Findings may not even be comparable due to methodological differences.

This is particularly troublesome in an international policy context like the European Union, when it needs to be determined, what are the consequences of climate change on the competiveness of Europe as a whole or the territorial cohesion of European regions.

Therefore, the ESPON Climate project developed a new comprehensive vulnerability assessment methodology and applied it to all regions across Europe in order to create the evidence base needed for a climate change responsive European territorial development policy. However, any vulnerability assessment is confronted with uncertainty which is based in the models (the project made use of CCLM), the emission scenario (A1B) and of course, the future trends in socio-economic development. Thus, the results of ESPON Climate have to be seen as a possible vulnerability scenario which shows what Europe's future in the wake of climate change may look like and not as a clear-cut forecast. Nonetheless, it gives some evidence based hints as to what adaptation should be about in view of the identified regional typologies of climate change.

2. Conceptual and methodological framework

The ESPON Climate project uses a conceptual framework that is widely used in the climate change and impact research community (see Table 1). According to this framework rising anthropogenic greenhouse gas emissions contribute to global warming and thus to *climate change*. This anthropogenic contribution runs parallel to natural climate variability. The resulting climate changes differ between regions, i.e. each region has a different *exposure* to climate change. In addition, each region has distinct physical, environmental, social, cultural and economic characteristics that result in different *sensitivities* to climate change. Together exposure and sensitivity determine the possible *impact* that climatic changes may have on a region. However, a region might in the long run be able to adjust, e.g. by increasing its dikes. This *adaptive capacity* enhances or counteracts the climate change impacts and thus leads to a region's overall *vulnerability* to climate change.

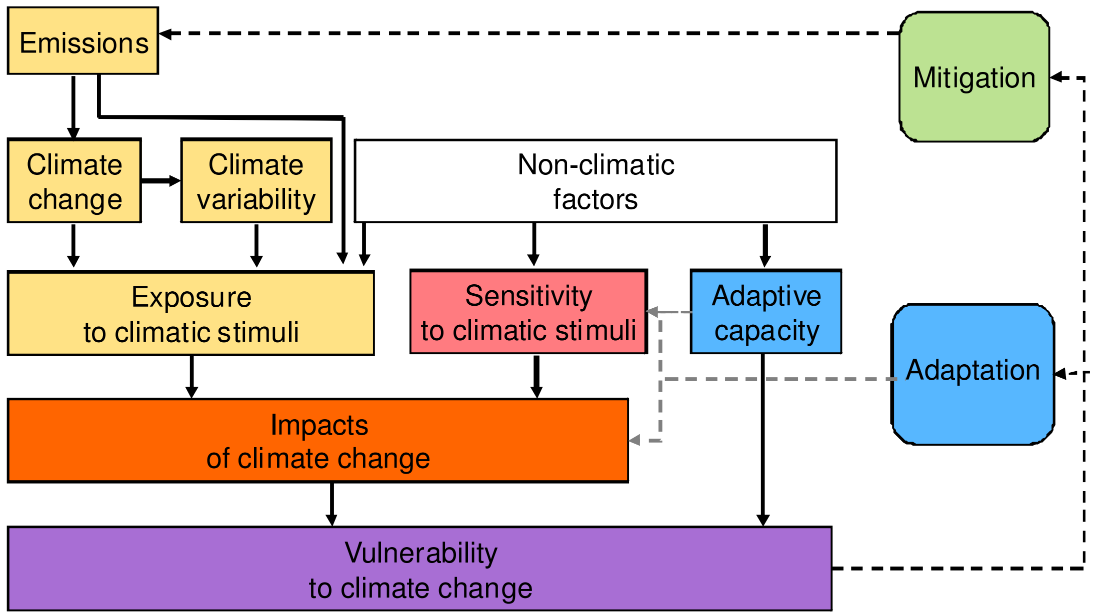


Figure 1: ESPON Climate Change research framework (adapted from Füssel & Klein, 2006, p. 54)

Following this framework the project's methodology consisted of the following main components. The *exposure analysis* focused on the climatic changes as such. It made use of existing projections on climate change and climate variability from the CCLM climate model, whose results have been used, among others, by the 4th IPCC assessment report on climate change. Using the IPCC climate scenario A1B (Nakicenovic et al. 2000) the ESPON Climate project aggregated data for two time periods (1961-1990 and 2071-2100) for eight climate stimuli. River flooding and sea level rise were added as two immediate 'triggered effects' of these climate stimuli.

Each region was then assessed in regard to its climate change *sensitivity*. For each sensitivity dimension (physical, environmental, social, economic and cultural) several sensitivity indicators were developed. Each indicator was calculated in absolute and relative terms and then combined. This integrated two equally valid perspectives on sensitivity: While relative sensitivity (e.g. density of sensitive population) is advantageous from a comparative point of view, the absolute sensitivity (e.g. absolute number of sensitive inhabitants) is more relevant from a policy/action point of view.

Exposure and sensitivity were then combined to determine the potential *impacts* of climate change. The analysis thus focused on what would be the result if climate change took place unrestrictedly and impacted on the regions without further preparation. For determining impacts each sensitivity indicator was related to one or more specific exposure indicator(s). For example, heat sensitive population (persons older than 65 years living in urban heat islands) were related to changes in the number of summer days (above 25°C), while forests sensitive to fire were related to summer days and summer precipitation. After determining the individual impacts, all impacts of one dimension were aggregated. The impact values of the five sensitivity dimensions were finally combined to one overall sensitivity value. This combination was calculated on the basis of relative weights, which were determined through a Delphi survey among the members of the ESPON Monitoring Committee.

The integration of exposure, sensitivity and adaptive capacity and particularly in between these dimensions raises particular issues induced by the theoretical framework. At these stages of the analysis process weighting issues occur. They ultimately refer to normative questions, as cultural beliefs and political preferences influence the weighting of factors such as social or economic sensitivity on the aggregated regional level (e. g. value of human lives against economic damages). Using a Delphi-based approach a questionnaire survey was conducted among the ESPON monitoring committee. The participants were asked to propose individual weights for all relevant stages. The results provided valuable input for the quantitative analysis of the European vulnerability assessment and reflect the collective assessment of the relative importance of each sensitivity and adaptive capacity dimension (cp. Table 1). The weighting between the different dimensions was balanced so that equal weights were applied between exposure and sensitivity as well as between impact and adaptive capacity.

Sensitivity		*Adaptive capacity*	
Cultural sensitivity	0.1	Economic resources	0.21
Economic sensitivity	0.24	Knowledge and awareness	0.23
Environmental sensitivity	0.31	Infrastructure	0.16
Physical sensitivity	0.19	Institutions	0.17
Social sensitivity	0.16	Technology	0.23

Table 1: Weights resulting from the Delphi-based assessment

A third major component of the project was the assessment of *adaptive capacity* in regard to climate change, i.e. the economic, socio-cultural, institutional and technological ability of a region to adapt to the impacts of a changing regional climate. This could mean preventing or moderating potential damages but also taking advantage of new opportunities. Several indicators were developed for each of the five major determinants of adaptive capacity. The individual indicators were subsequently combined for each determined and finally aggregated to an overall adaptive capacity. This aggregation was again conducted on the basis of the Delphi survey results.

To determine the overall *vulnerability* of regions to climate change the impacts and the adaptive capacity to climate change were combined for each region. The underlying rationale is that a region with a high climate change impact may still be moderately vulnerable if it is well adapted to the anticipated climate changes. On the other hand, high impacts would result in high vulnerability to climate change if a region has a low adaptive capacity.

Mitigation is also highly relevant for territorial development and cohesion since climate policy implementation and the transition to a low-carbon society will have differential effects on sectors and regions. Mitigation measures, even implemented at the regional level, will not have significant effects on regional climate but only contribute to an overall reduction of global climate change. Therefore the project's mitigation analysis could only determine the mitigation capacity of each region but cannot determine what effect this would have locally or regionally.

Figure 2 describes the individual steps of the vulnerability assessment and may serve as a general orientation. Each step is described in detail in the full scientific report. Note that all numbers shown in the diagram are only examples intended to make the various calculation procedures more transparent.

The seven case studies of the ESPON Climate project serve to cross-check and deepen the findings of the pan-European assessment of the other research actions. They provide in-depth regional analyses of climate change vulnerability (exposure, sensitivity, impact, adaptation). The studies cross-check the indicators and findings of the European-wide analysis with the results of the case study areas, but explore also territorially differentiated adaptation strategies to climate change.

Reflecting on the project's methodology a number of key features and challenges are apparent. First of all the project used a generally accepted conceptual framework and on this basis was able to build a coherent vulnerability assessment methodology. Nevertheless, the selection, calculation and aggregation of the individual indicators involves not only scientific knowledge, but also normative decisions on what aspects of such concepts as climate change, sensitivity or adaptive capacity are to be captured and assessed. In addition the choices of indicators are also shaped by the availability and quality of statistical data. Lastly, most of the indicators finally used in the project are made up of several input variables. The construction of such composite indicators is challenging as it involves different choices on selection of data, normalisation procedures, weighting schemes and aggregation methods (Saltelli, Nardo et al. 2004).

Implicitly the data selection also involves choices regarding underlying climate scenarios and models. To gain evidence on the spatio-temporal distribution and variability of projected developments the ESPON climate project refered to the Intergovernmental Panel on Climate Change (IPCC) scenarios (Nakicenovic et al. 2000). At first the project included both the A1B and B1 scenarios, but it became obvious that the B1 calculations are futile due to the fact that human GHG emissions have already reached the high-end of the IPCC scenarios, i.e. A1FI. It was thus decided to only continue with the A1B scenario as it displays a reasonable average (in case emissions would in fact decrease). Furthermore one global circulation model (ECHAM5/MPI-OM) and one regional circulation model (CCLM) was chosen due time and financial constraints and the fact that it covers almost the entire ESPON space.

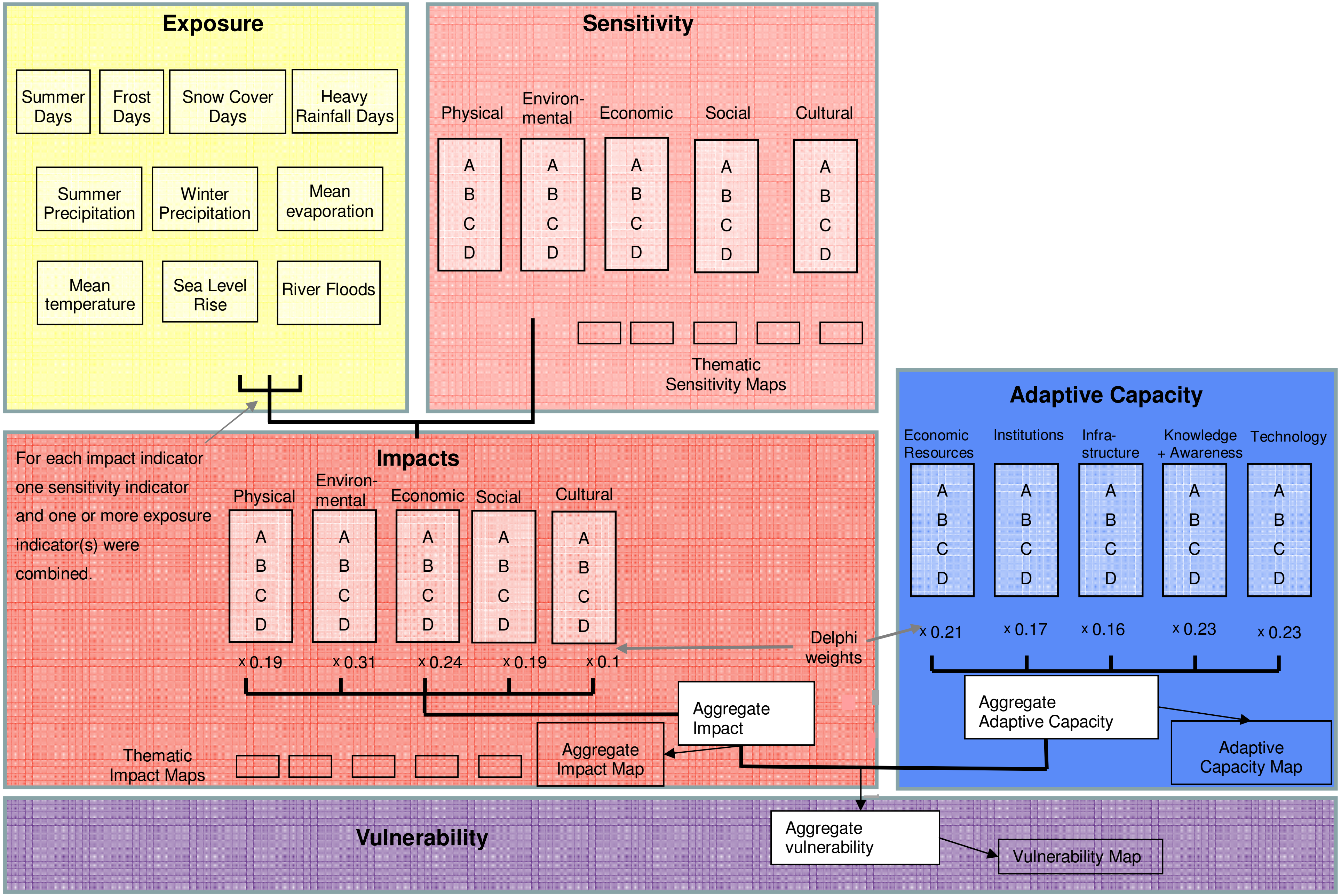


Figure 2: Overview of the ESPON Climate vulnerability assessment methodology

3. Climate change and Europe's regions: Key findings

3.1 Patterns of climatic changes across Europe

Climate change exposure refers to the nature and degree to which a system is exposed to climatic variations. This exposure depends on global trends of climate change and - due to spatial variations - on the system's location (cp. Füssel/Klein 2006, 313). Both general and regional climatic changes are modelled in the CCLM climate model, upon which the exposure analysis of the ESPON Climate project is based.

3.1.1 Indicators on exposure to climate stimuli

The CCLM model delivers a wide range of climate-related output parameters (cp. Wunram 2007). For almost all output parameters, the model provides data on an hourly to daily basis. Using the A1B climate scenario selected parameters of the CCLM model were aggregated by one of the project partners, the Potsdam Institute of Climate Impact research (PIK) for the time periods. Hence, for the purpose of this research project the differences between the mean values of these two 30-year time periods were defined as climate change.

The selected climatic variables listed below reflect on a wide range of climatic conditions, from temperature to hydrologic variables. For a complete definition and discussion of these variables see the extended scientific report.

1) *Change in annual mean temperature*

2) *Change in annual mean number of frost days* (min temp <0°C)

3) *Change in annual mean number of summer days* (max temp > 25°C)

4) *Relative change in annual mean precipitation in winter months* (December to February)

5) *Relative change in annual mean precipitation in summer months* (June to August)

6) *Change in annual mean number of days with heavy rainfall* (above 20kg/sqm)

7) *Relative change in annual mean evaporation*

8) *Change in annual mean number of days with snow cover*

In addition two 'triggered effects', which constitute a culmination of several of the above variables, were also included:

9) *Change of inundation through river flooding*

10) *Change of inundation through coastal storm based on projected sea level rise*

As examples the regional patterns of six of these variables are depicted and briefly discussed before presenting the results of a multi-variant cluster analysis.

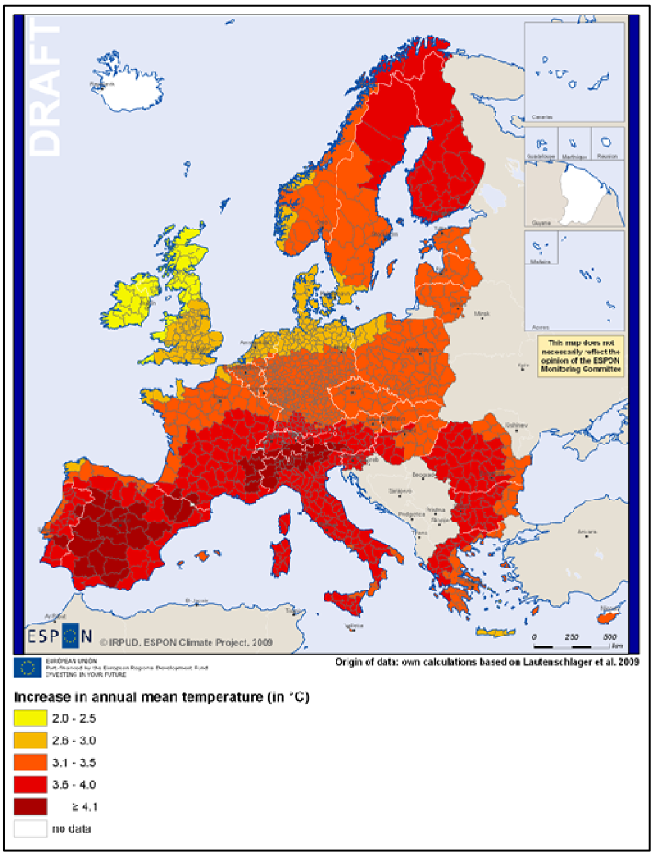


Figure 3: Change in annual mean temperature

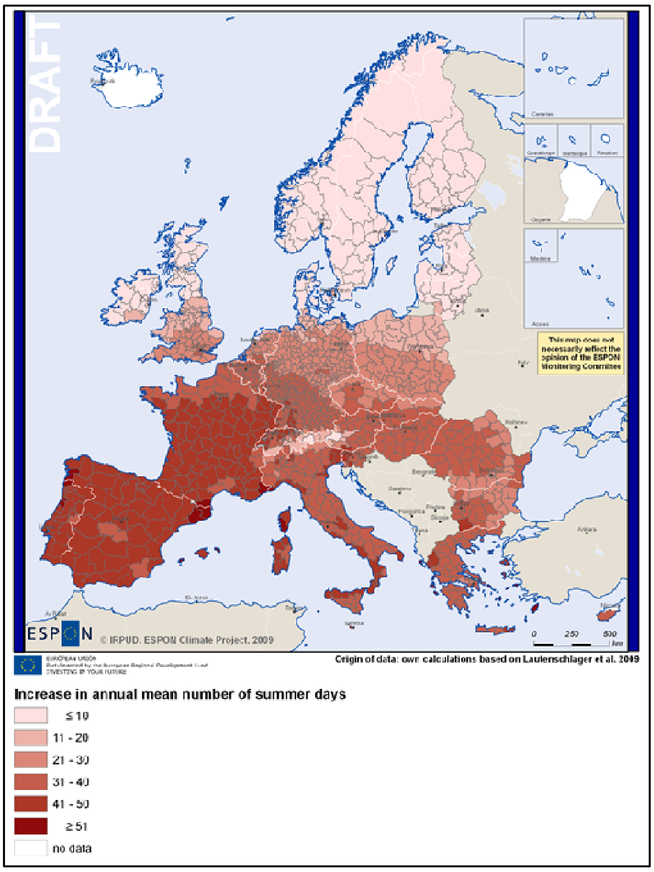


Figure 4: Change in annual mean number of summer days

The projected changes in ***annual mean temperature*** indicate increasing temperatures between 2 and over 4.1 degrees for the ESPON territory (see Figure 3). The UK, Ireland, Denmark, parts of The Netherlands and northern parts of Germany exhibit the comparatively lowest temperature changes of up to 3 degrees Celsius. Western and northern parts of France, Belgium, most parts of Germany, Poland, the Czech Republic and Slovakia as well as southern parts of Sweden and Norway and the Baltic states will be subject to temperature increases between 3 and 3.5 degrees Celsius. Southern and South-Eastern Europe (except for some parts of Greece, Bulgaria and Romania) as well as Northern Scandinavia and Finland are projected to experience the comparatively highest temperature changes with absolute changes of more than 3.5 degrees Celsius. Spain, parts of Portugal but also parts of the Alpine Space will even experience temperature changes of more than 4 degrees Celsius according to the CCLM projections.

The patterns of the projected changes of the annual mean number of ***summer days*** are mapped in Figure 4. It shows increases between less than 10 and more than 50 days per year. The comparatively slightest increases are predicted for the North of Europe including Scandinavia, Finland, the Baltic States as well as parts of Denmark, UK and Ireland, while most of France, Spain and Portugal exhibit increases of more and 40 days per year on average.

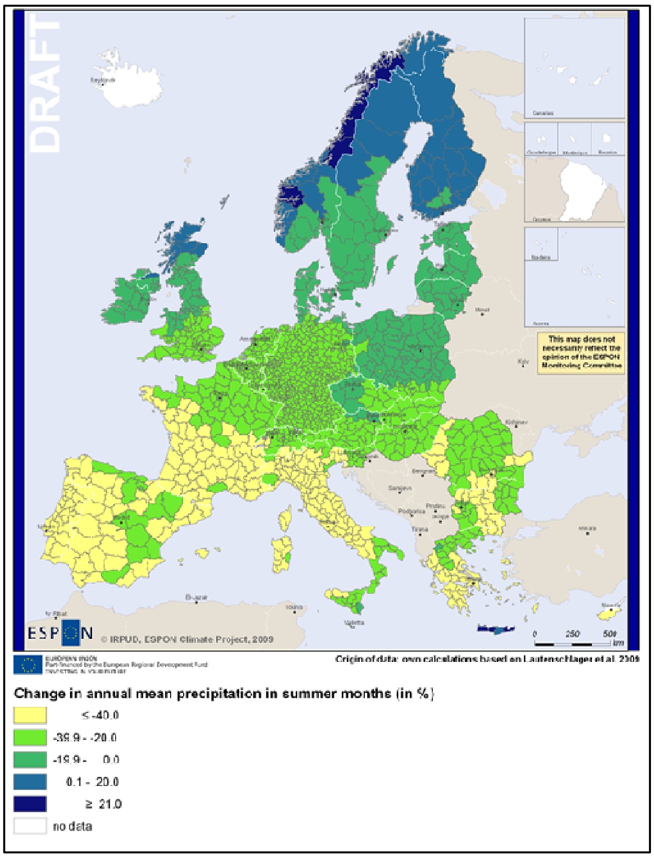


Figure 5: Relative change in annual mean precipitation in summer months

The CCLM outputs for ***precipitation in summer months*** again are twofold considering the changes across the European territory (see Figure 5). While parts of Scandinavia and Finland as well as Northern UK are projected to experience *in*creases of up to 40%, most of the ESPON space will experience a *de*crease in summer precipitation of up to 40% and more. For parts of Scandinavia, the Baltic states, Poland, parts of the Czech Republic, Denmark, Ireland and parts of the UK those decreases are projected to range up to 20% while the rest of Europe and here particularly France, Portugal, Spain Italy and Greece are projected to experience the strongest relative decreases in annual summer precipitation.

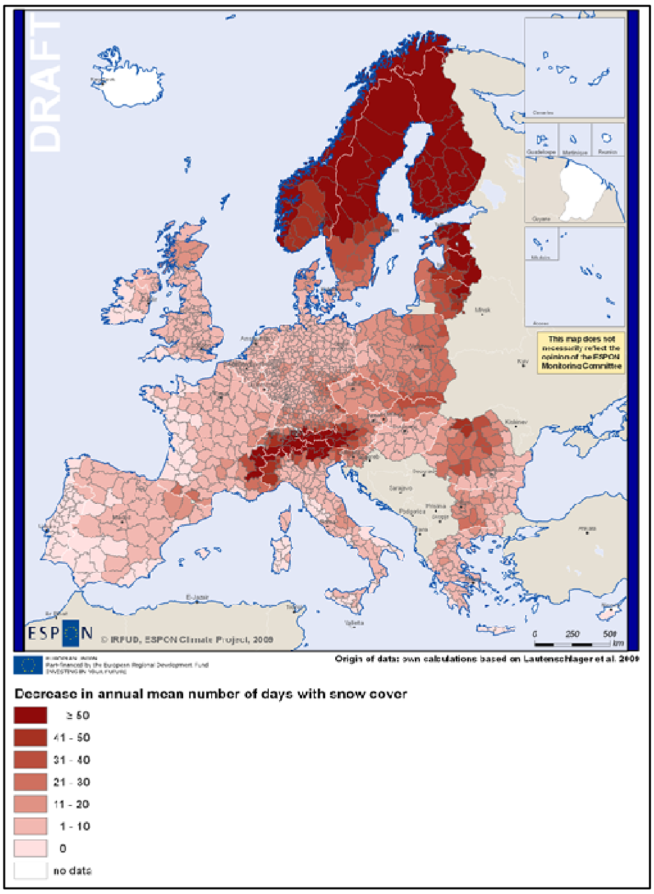


Figure 6: Change in annual mean number of days with snow cover

Another CCLM variable provides evidence for **days with snow cover** and has been calculated as change in annual mean number of days. The resulting pattern indicates that snow cover is projected to decrease most significantly in Scandinavia, Finland, the Baltic States and the Alpine Space (see Figure 6) with numbers ranging from decreases of 40 to more than 50 days. Next to these regions some parts of Eastern Europe are also projected to experience comparatively strong decreases in the number of days with snow cover. The rest of the European territory will mostly experience decreases in snow cover from 0 to 15 days.

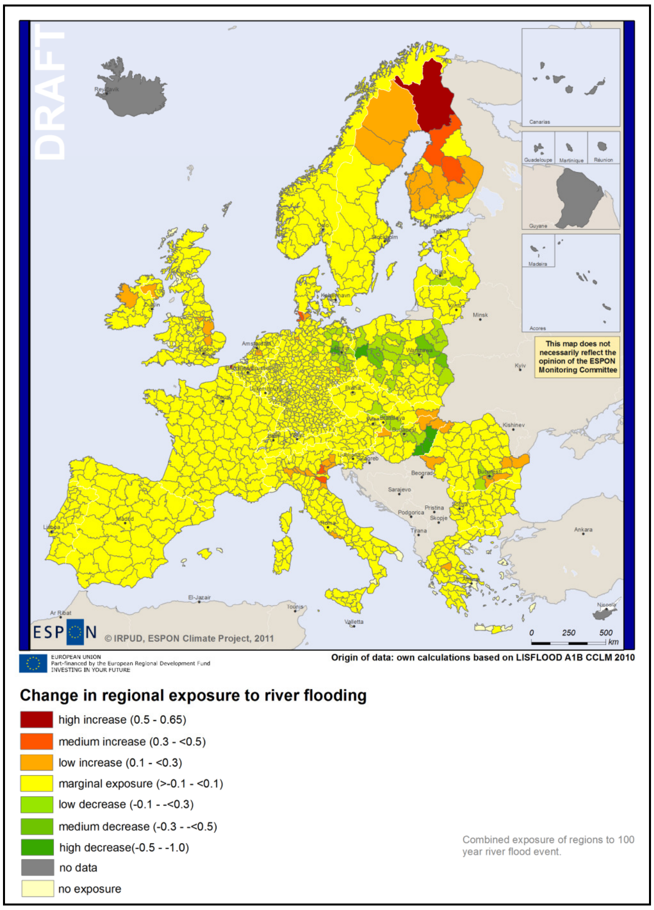


Figure 7: Change in regional exposure to river flooding

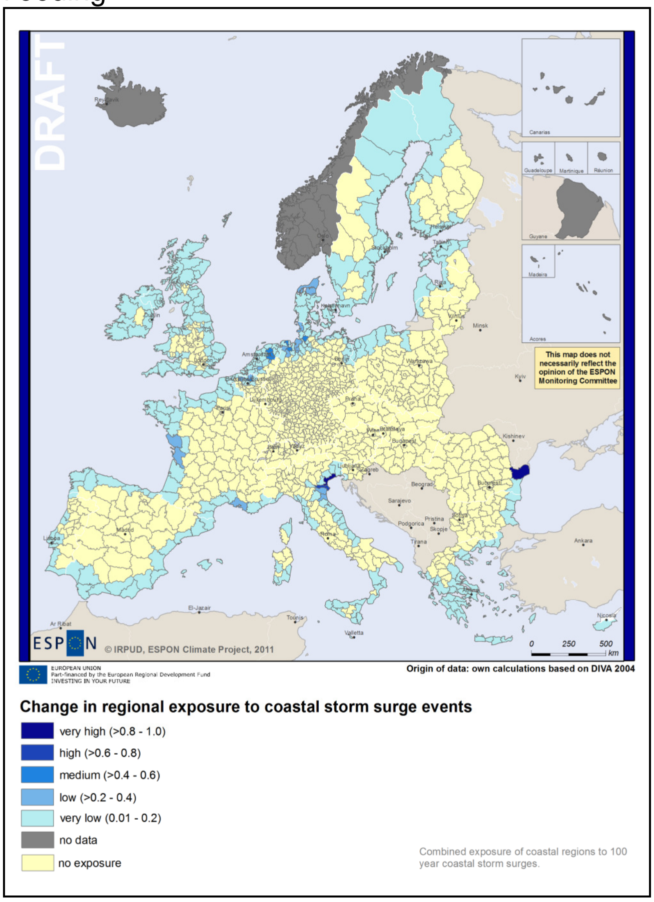


Figure 8: Change in exposure to coastal flooding

Change in exposure to ***river flooding*** has been calculated based on data provided by JRC's LISFLOOD model (cp. van der Knijff and de Roo 2008). In 2010 this model was run on the basis of the climate projections from the CCLM model considering the A1B scenario. The outputs are grids with inundation depth along major European rivers. The ESPON Climate project used these outputs to calculate changes in regional inundated area of a 100 year return event, comparing the past with the future time period. The results of these calculations (Figure 7) show that for most regions changes are rather marginal, but some regions exhibit considerable changes. Among the areas characterised by considerable increases in river flooding are regions located in Northern Scandinavia and Northern Italy. Also some regions In UK, Ireland, Hungary and Romania are quite severely affected. Corresponding to the precipitation patterns there are also some regions projected to experience decreases in exposure to river flooding, predominantly in eastern parts of Germany, in Poland and Hungary.

For ***coastal flooding***, storm surge heights of a 100-year return event were derived from DIVA projections (cp. Vafeidis et al. 2005). In order to incorporate climate change it was assumed that due to sea level rise these storm surge heights would increase by one metre. Consequently, based on the global digital elevation model Hydro1k (USGS 2010) it was calculated which areas would be additionally inundated by coastal flooding (beyond the 1961-1990 inundated areas).

The results shown in Figure 8 illustrate that for most coastal regions changes in inundated area will be rather marginal. However, for some regions more severe changes can be expected. This affects primarily regions at the Dutch and German coastlines but also in Denmark and France. The most severe changes, however, can be projected for some regions in north-eastern Italy and a coastal region in Romania.

3.1.2 Typology of climate change regions

A typology of climate change regions was developed by performing a series of cluster analyses on the basis of the eight CCLM climate variables. In the end five clusters were identified, each exhibiting distinct regional climate change profiles (see Figure 9). It needs to be emphasised that the map does not show climate regions but rather climate *change* regions.

The results seem plausible as main topographic characteristics of Europe are distinguishable, underlining the validity of the derived typology at least from a pan-European perspective. On the regional level the case studies conducted within this research project shed further light on local variations of climate change.

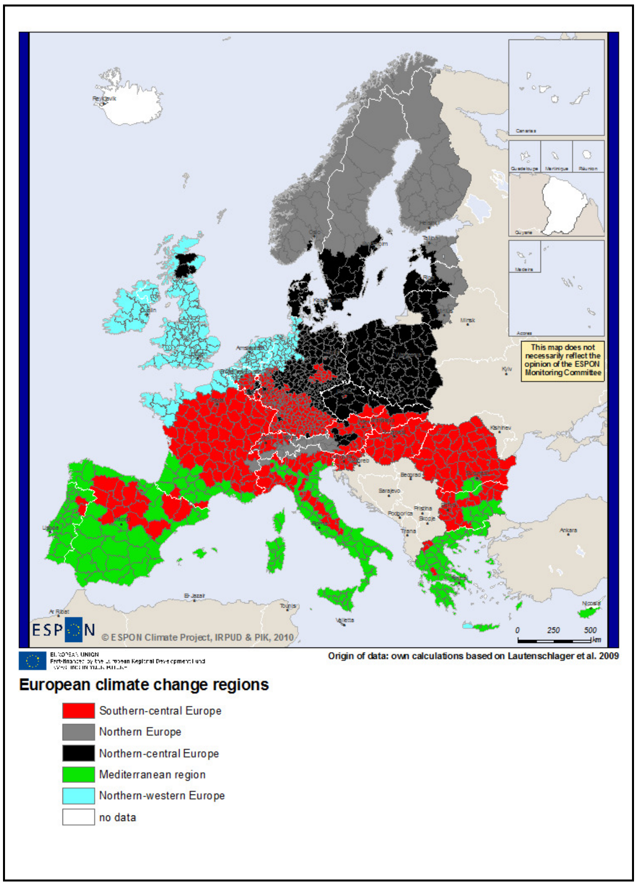


Figure 9: Map of the climate change typology

A strong increase in mean temperature is observable for three clusters, namely 'Northern Europe', 'Southern central Europe' and the 'Mediterranean region'. Strong decreases in frost days predominantly characterise the clusters of 'Northern central Europe, 'Northern Europe' and 'Southern central Europe', whereas strong increases in summer days is projected for the clusters of 'Southern central Europe' and the 'Mediter-ranean region'. Change in precipitation in winter months in the 'Northern Europe' cluster shows particularly strong increases while for summer months most significant changes in terms of strong decrease can be observed in 'Southern central Europe' and 'Mediterranean region' clusters. The variables heavy rainfall and evaporation do not show very strong changes for any of the clusters while days with snow cover are projected to decrease strongly in the 'Northern central Europe' cluster.

3.2 Europe's regions and their different sensitivities to climatic changes

According to the IPCC, sensitivity is defined as "the degree to which a system is affected, either adversely or beneficially, by climate-related stimuli. The effect may be direct (e.g. a change in crop yield in response to a change in the mean, range, or variability of temperature) or indirect (e.g. damages caused by an increase in the frequency of coastal flooding due to sea-level rise)." (IPCC 2007c).

However, not every element of the system is sensitive to every climate-related stimulus. Thus, it has to be clarified, based on literature, which stimulus exactly affects which element of the system. Moreover, the same stimulus may affect the system territorially differently: The same change in summer temperature may affect the tourist sector positively or negatively depending on the existing climatic conditions, the agricultural sector may benefit from an in increase in precipitation or not depending on various factors.

ESPON Climate defined five dimensions of sensitivity which are described in more detail in the following section (see the scientific report for a more detailed documentation of each sensitivity indicator and related connections to climatic stimuli).

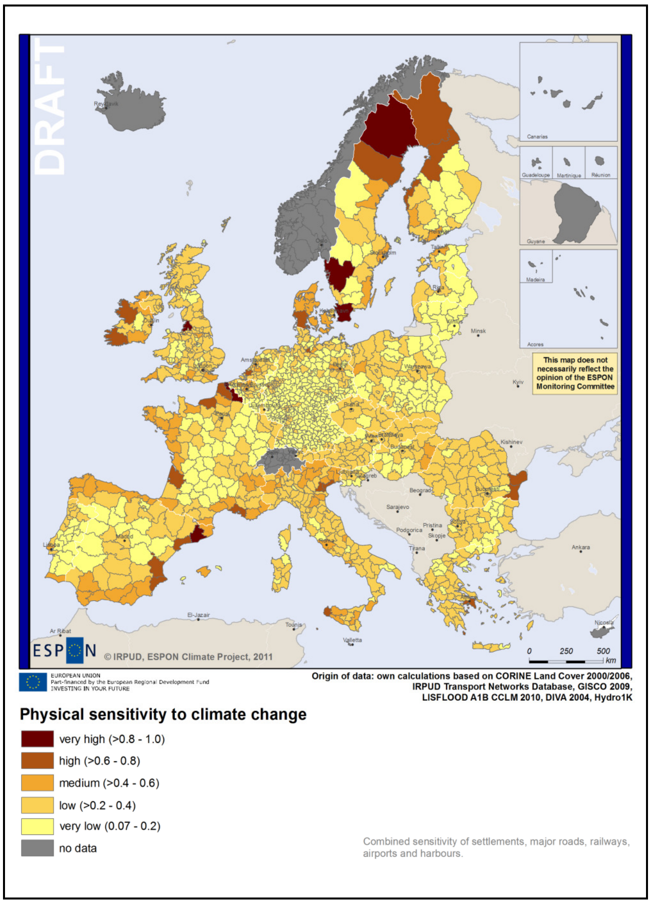


Figure 10: Physical sensitivity

Combined physical sensitivity

Physical sensitivity relates to all human artefacts that are important for territorial development and which are potentially affected by climate change. This includes settlements, roads, railways, airports and harbours. These physical assets of a region are typically adapted to normal regional weather conditions and can withstand smaller climatic changes. However, buildings and infrastructure are sensitive to extreme weather events like flash floods, large-scale river floods and coastal storm surges which's frequency and magnitude may change due to climate change.

The map shows that in Europe the physical assets that are sensitive to these extreme weather events are mainly concentrated along the coastline.

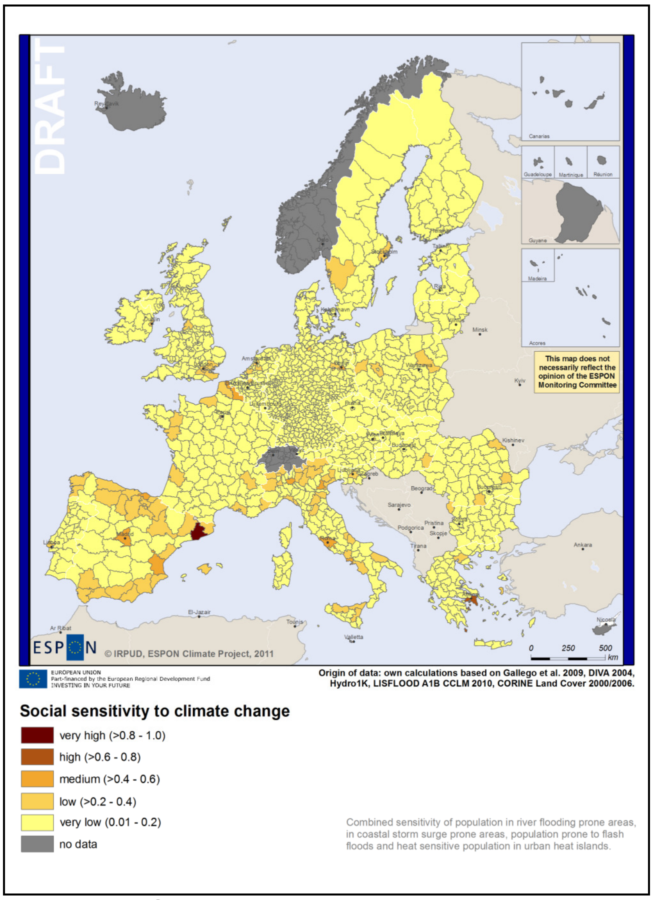


Figure 11: Social sensitivity

Combined social sensitivity

Social sensitivity relates to human populations that may be adversely or positively affected by climate change. In particular, this encompasses climate-related sensitivities in regard to public health and personal mobility. In particular this dimension includes populations sensitive to river flooding, coastal flooding, flash floods and heat (i.e. senior citizen in urban heat islands).

Figure 11 shows that these populations are mainly concentrated in Southern European agglomerations and along the coastline. In fact, the most sensitive regions are coastal agglomerations in the Mediterranean. This may in part reflect the higher population densities of these cities compared to northern European cities.

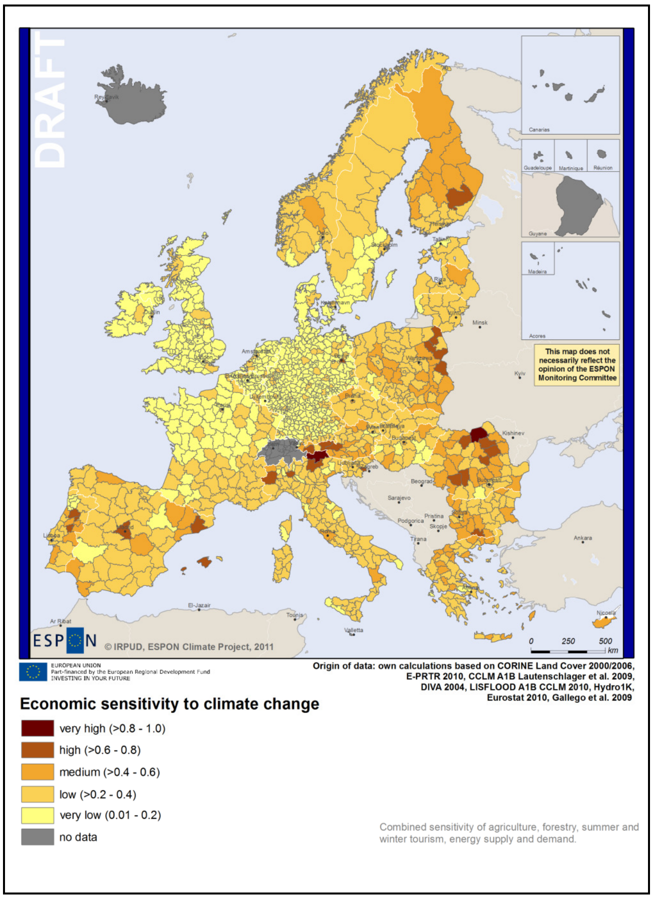


Figure 12: Economic sensitivity

Combined economic sensitivity

Economic sensitivity related to economic activities or sectors that are especially sensitive to climatic changes. This includes agriculture and forestry whose economic goods are highly dependent on suitable climate. Tourism, both summer and winter tourism, capatilizes on specific climatic conditions. The energy sector is also very sensitive: Power plants need water for cooling and are sensitive to flooding. Private households and the service sector require heating and/or cooling and thus deman more or less energy.

Consequently Figure 12 highlights particularly those local economies which are dependent on tourism, agriculture and forestry: the Mediterranean region, the Alps, large parts of Eastern Europe, but also Scandinavia (energy demand for heating!).

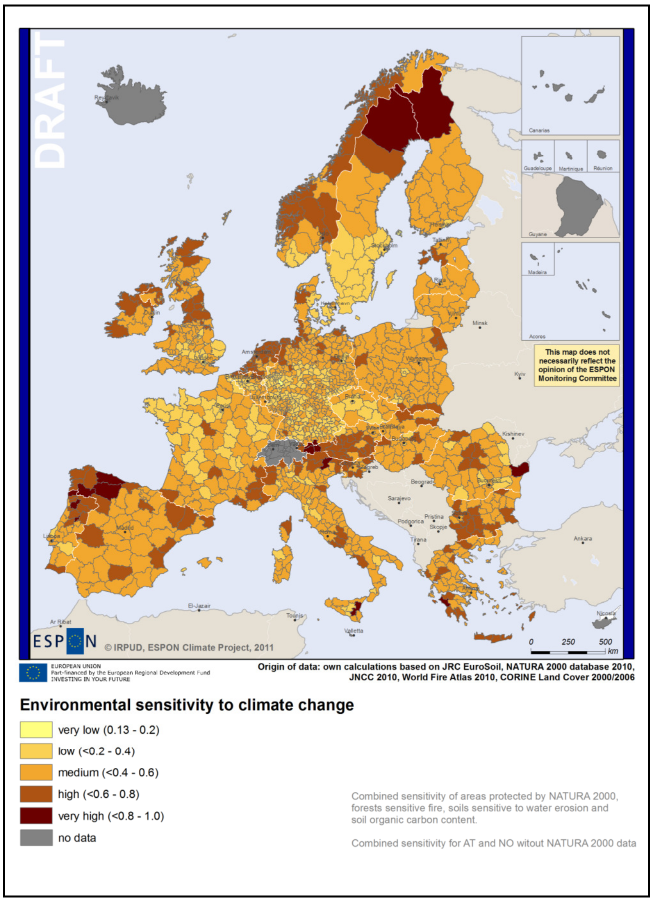


Figure 13: Environmental sensitivity

Combined environmental sensitivity

Climate is an integrated part of nature and thus directly or indirectly affects all other parts of nature. However, many plants and animals are able to cope with climatic changes, e.g. by migration or genetic adaptation. Thus the environmental sensitivity dimension focuses on natural entities that are highly sensitive (like protected natural areas or especially fire prone forests) and relatively stable entities like soils, that have only limited capacities to adapt and at the same constitute the basis for animal and plant ecosystems.

Figure 13 shows that especially mountain and river delta regions have protected natural areas and/or possess sensitive soils and forests.

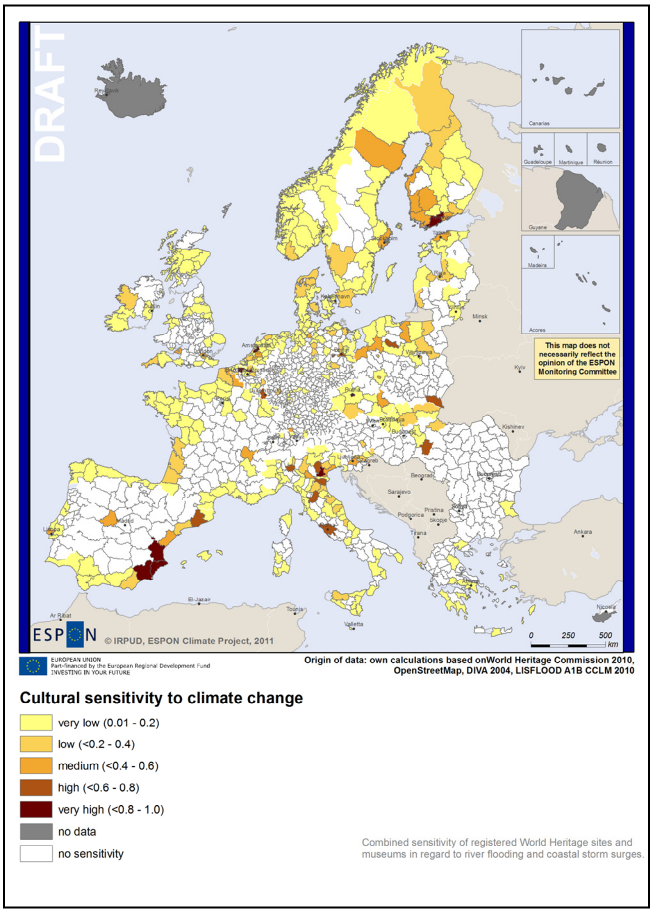


Figure 14: Cultural sensitivity

Combined cultural sensitivity

Cultural sensitivity encompasses cultural assets like museums and internationally recognised historic sites that may potentially be damaged or destroyed due to climate change. While this may to a minor degree be true for all temperature and moisture changes, the highest and most sure sensitivity relates to extreme weather events like river flooding and coastal flooding.

Figure 14 therefore shows concentrations of sensitive cultural assets in regions along the coasts and along major rivers. Coastal cities like Barcelona, Rome or Venice with their outstanding cultural heritage can easily be distinguished. But also some inland regions exhibit high cultural sensitivity values, owing to the fact that many old cities and historic sites are deliberately located along major rivers.

3.3 The impacts of climate change on Europe's regions

The IPCC defines impact as "[c]onsequences of climate change on natural and human systems. Depending on the consideration of adaptation, one can distinguish between potential impacts and residual impacts." (IPCC 2007c) According to the conceptual framework, on which ESPON Climate is based, impacts may occur given a projected change in climate, without considering adaptation (potential impacts). However, the capacity to adapt is considered as a separate element of the conceptual framework and is discussed in section 3.4.

The pattern of impacts of climate change on Europe's regions should be seen as evidence basis for adaptation needs: the more the potential impacts increase, the more important is adaptation in order to avoid negative consequences on the economy, population, physical assets, cultural heritage and the environment.

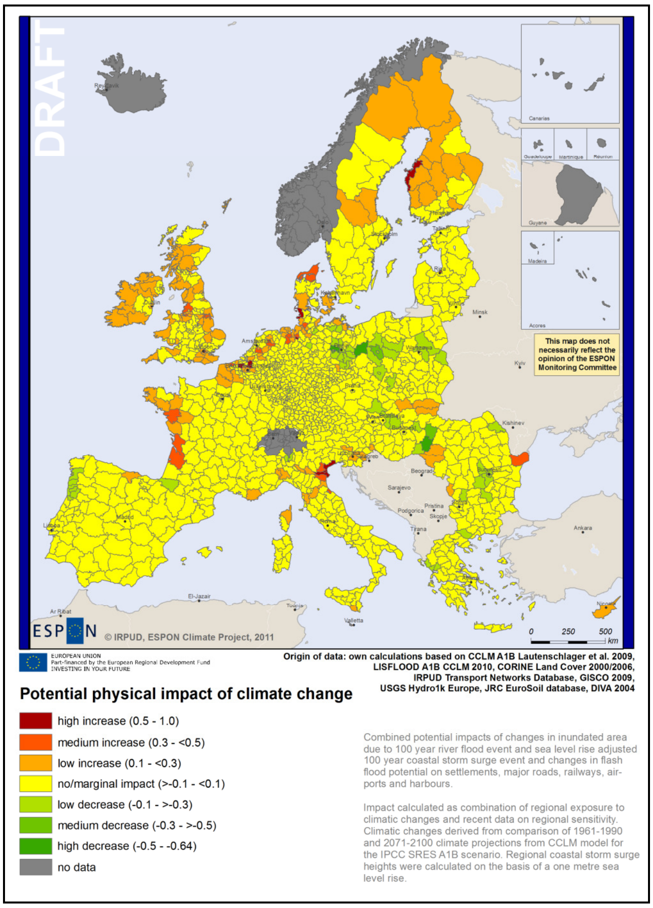


Figure 15: Potential physical impact

Potential physical impact

Physical structures such as settlements and transport infrastructure are mainly sensitive to changes in extreme events. This explains the remarkably high impact in north-western European coastal regions, which border the Atlantic Ocean. This pattern results from sea level rise and a projected increase in river floods. It fits well with the climate change types North-western and Northern Europe which came out of the cluster analysis. Other small hot spots in Northern Italy (Po river valley, Venice) are caused by similar reasons. However, large parts of Europe may not expect relevant impacts on their infrastructure resulting from climate change. Nonetheless, most river valleys in Europe may be prone to river flooding, but this does not apply to Eastern Europe because of decreasing precipitation.

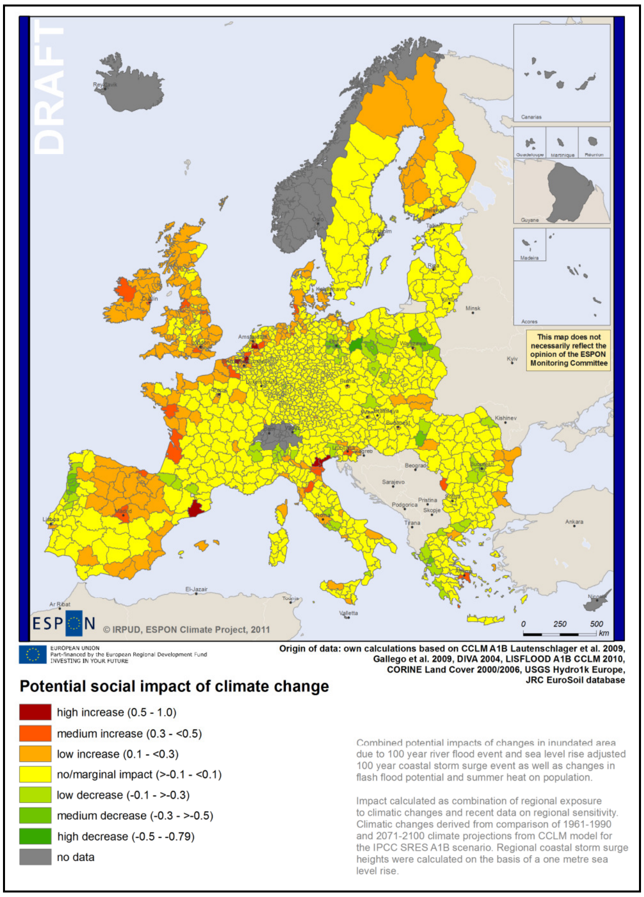


Figure 16: Potential social impact

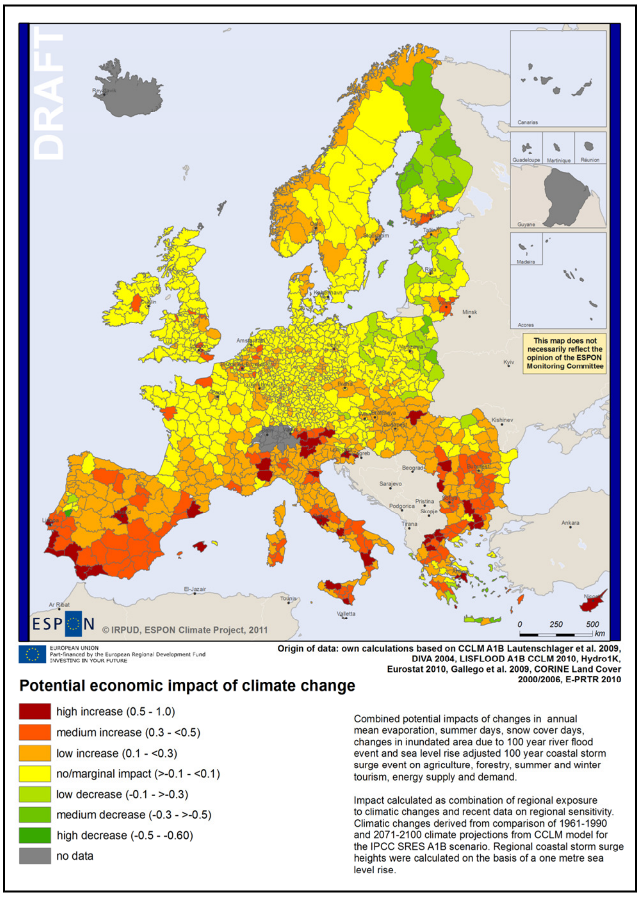


Figure 17: Potential economic impact

Potential social impact

Europe's population is mainly sensitive to extreme events which are driven by climate change (sea level rise in combination with storm surges, river flooding, flash floods, but also heat). Sensitivity to these changes is a matter of the distribution of age groups, but also the density and size of urban areas (urban heat island effect). Consequently, one can expect the population of Southern Europe's agglomeration areas to have a high impact. A similar impact, but for different reasons, is projected for large parts of North-West Europe and northern Scandinavia. Here the causing factors are the projected increase in river flooding and the consequences of sea level rise. In contrast, the population of large parts of the core of Europe is potentially not or only marginally affected by climate change.

Potential economic impact

What is clearly visible from the map is a south-north gradient: many economically important countries like Germany and the U.K. may expect only a low to marginal economic impact. The main reason for the gradient is the economic dependency of large parts of Southern Europe on (summer) tourism, but also agriculture. Both are projected to be negatively impacted due to the increase in temperature and decrease in precipitation while the environmental conditions for agriculture in North-Eastern Europe tend to be improved. Moreover, energy demands come into play through the increased need for cooling. However, the Alps as a premier tourist depended region are also identified as hotspot which mainly results from the projected decrease in snow cover. The economic impact in South Eastern Europe is a consequence of the impact on agriculture – which is still important there.

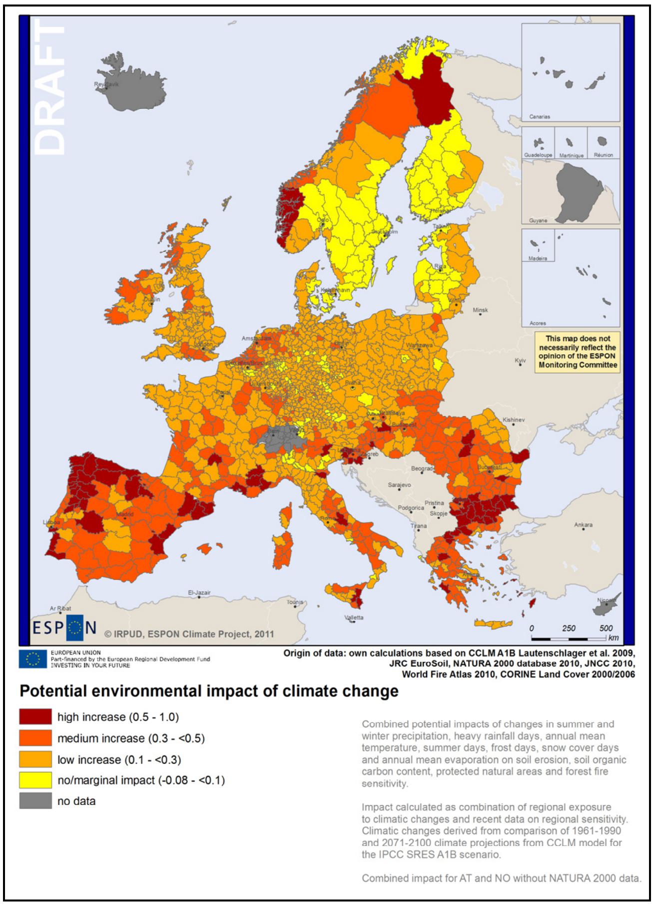


Figure 18: Potential environmental impact

Potential environmental impact

Figure 18 shows that climate change is expected to have the highest environmental impacts in the south and north of Europe – in particular in mountainous regions. Important factors are the high slopes and specific soil characteristics that facilitate soil erosion there. In the Mediterranean the drier and hotter climate also increase the likelihood of forest fire occurrence. Soils in river deltas or along coasts seem to also be negatively impacted by climate change. The severe impacts in northern Scandinavia are in part also due to their very large protected areas where *any* climatic change (in this case warmer and wetter climate) is considered as negatively affecting the specific ecosystems under protection.

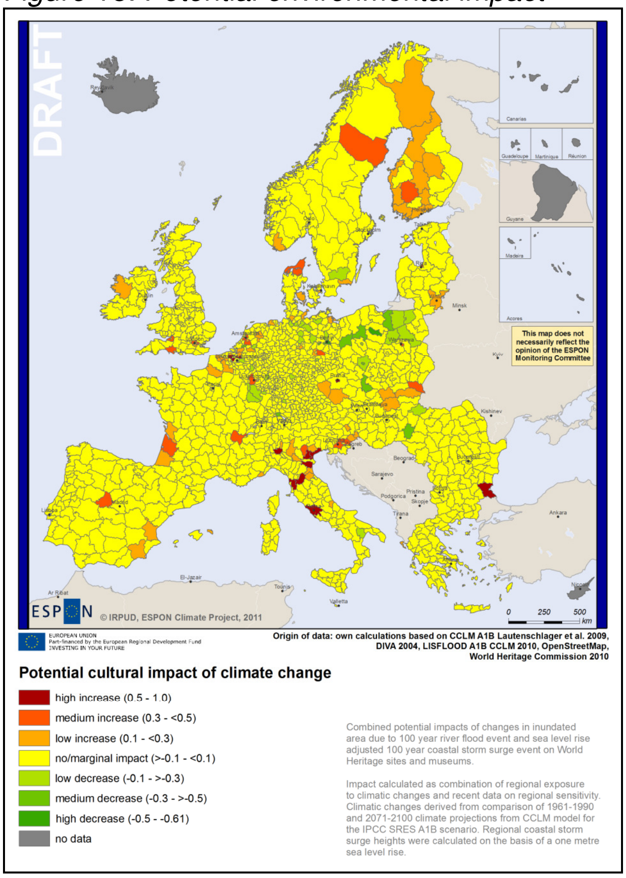


Figure 19: Potential cultural impact

Potential cultural impact

The potential impact of climate change on cultural assets is obviously an issue for a minority of European regions while most regions may expect no or just a marginal impact. This result mainly comes from the change of frequency and magnitude of extreme events, to which cultural heritage sites and museums are sensitive. Creeping changes in temperature and precipitation play hardly a considerable role for cultural heritage. Thus, the hotspots in Italy are a consequence of the projected in crease of flood hazard on the one hand and the density of cultural heritage sites in this country. Other remarkably impacted regions in the north of Europe are those which encompass some cultural sites and museums, and are most affected by an extreme increase in flooding.

Aggregate impact

The potential impact of climate change on Europe's regions differs considerably: hot spots are mostly in the South of Europe – i.e. the big agglomerations and summer tourist resorts at the coastline. However, other specific types of regions (e.g. mountains) are particularly impacted, but partly for other reasons (sea level rise, economic dependency on summer and/or winter tourism). There seems to be a moderate increase in some areas in northern Scandinavia. This results mainly from the sensitivity of the environment and flood prone infrastructure. All in all, two of the five climate change regions identified in the exposure analysis (see Figure 9: *Map of the climate change typology*) clearly come out of this map: North-western Europe and the Mediterranean region.

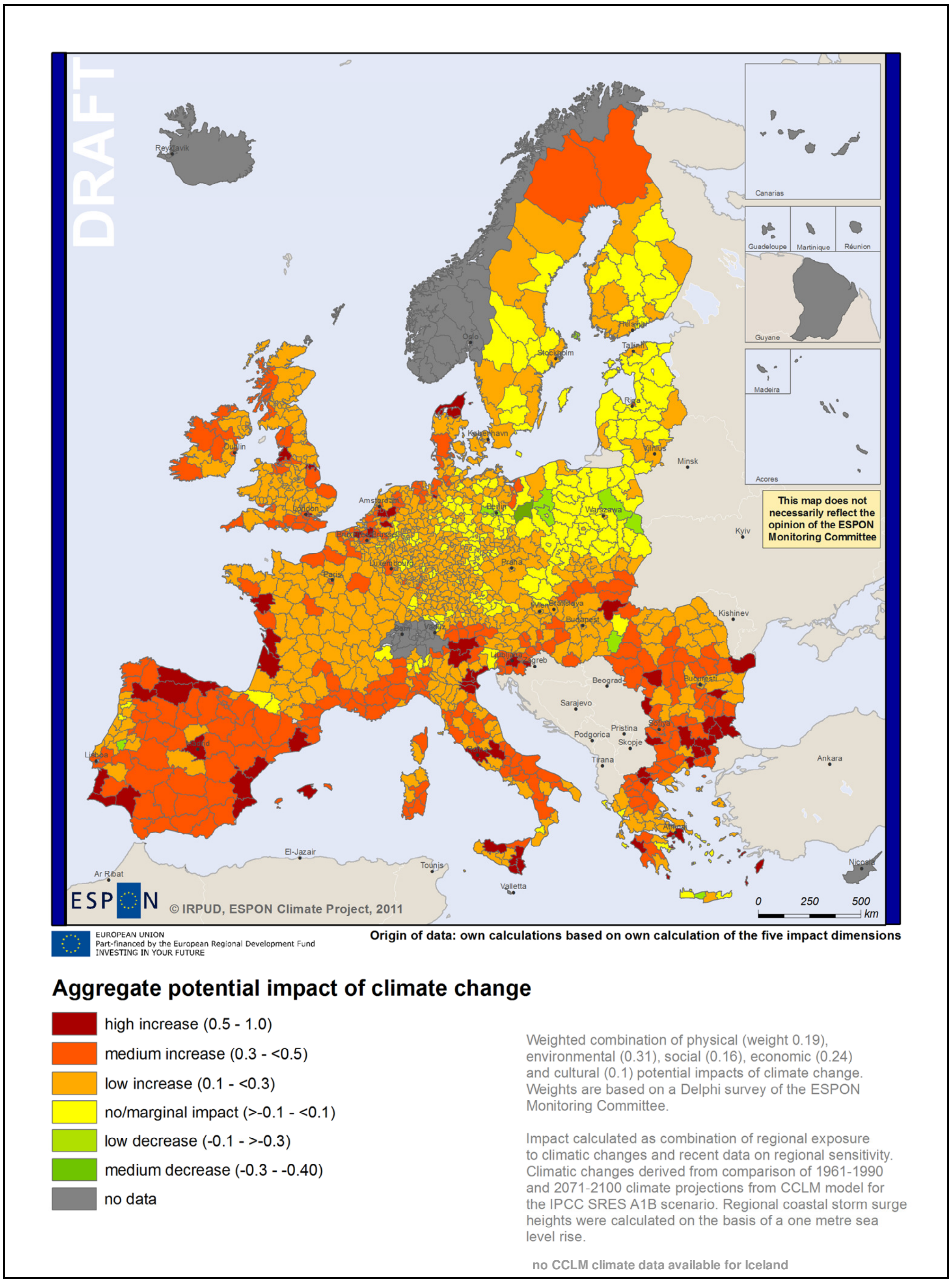


Figure 20: Aggregate potential impact

3.4 Regional capacities to adapt to climate change

Adaptive capacity is defined as the ability or potential of a system to respond successfully to climate variability and change, and includes adjustments in both behavior and in resources and technologies (IPCC 2007c). A system's adaptive capacity is mostly determined by a local set of resources and conditions that constrain or facilitate the ability of the system to successfully adapt to the changes in climate (Adger, Arnell & Tompkins 2005, Smit, Wandel 2006). Although it is acknowledged that adaptive capacity is a dynamic concept, it is possible to identify a set of determinants that affect a region's ability to adapt (Smit, Pilifosova 2001).

Here the focus is on generic determinants of adaptive capacity that can be measured across the regions in Europe. It is accepted that some determinants are generic in that they enable adaptation across the localities and countries irrespective of their location and climate impacts, whilst others are more specific to particular climate change impacts (IPCC 2007a). This study, along the lines of previous research of the ATEAM (Schröter et al. 2004) considers adaptive capacity to consist of three parts: awareness, ability and action, which are further comprised of determinants of adaptive capacity as defined by the IPCC and others, see Figure 2.

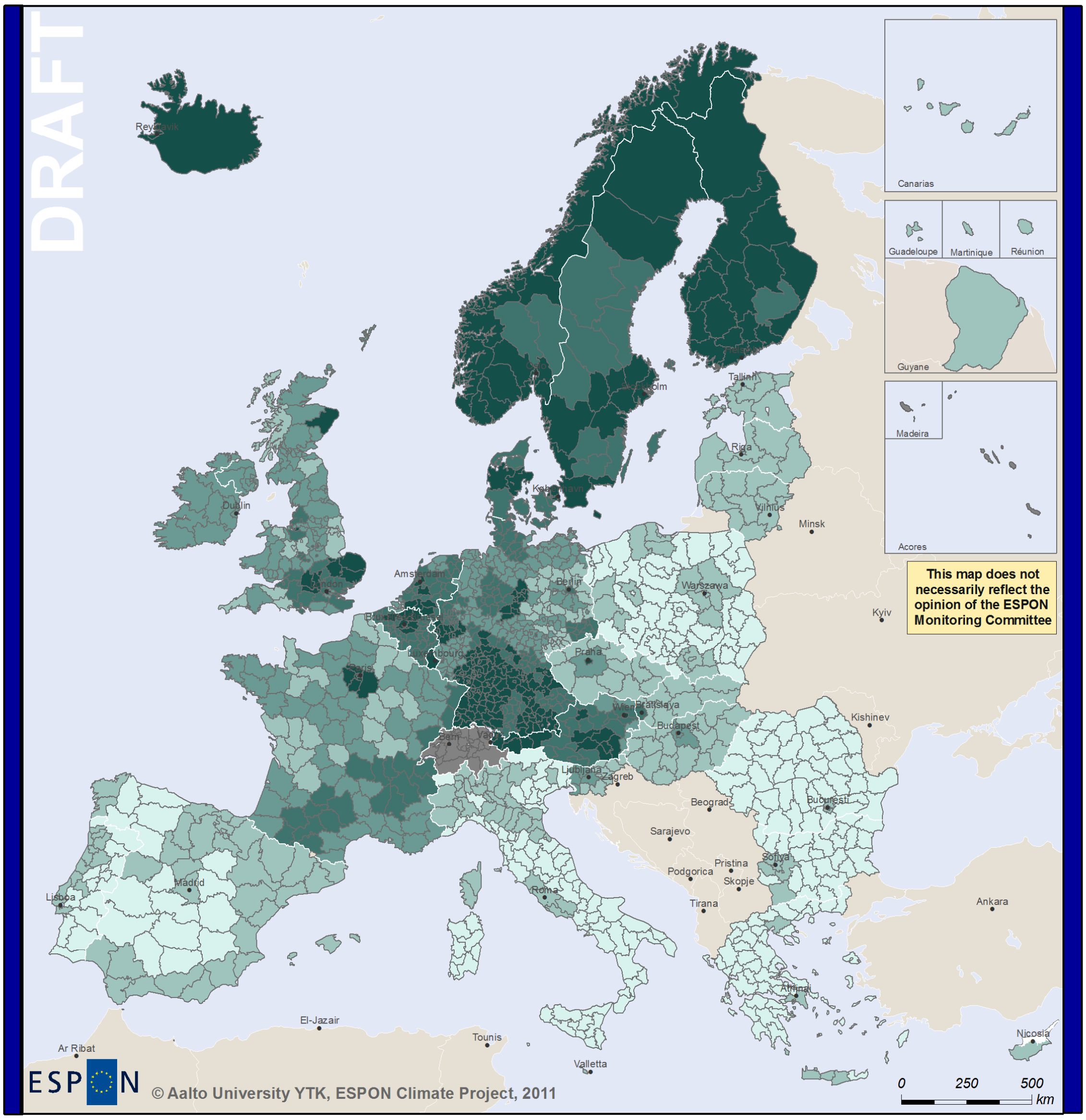
Figure 21 shows European regions' adaptive capacity, displaying several trends. In general terms, the Nordic countries have higher capacity than most of the Southern European countries. Also, in comparison, Eastern European countries, on the whole, have lower capacity than Western or Northern European countries. Overall, the countries around the Mediterranean appear to have lower capacity than the countries around the Baltic Sea region.

3.4.1 Capacities for mitigating climate change

Climate change mitigation comprises, in practice, activities focusing on decreasing net greenhouse gas emissions into the atmosphere, stressing the preventive nature of climate policy. Winkler et al (2007) point out that mitigative capacity is the ability to reduce greenhouse gas emissions in either absolute or relative terms and give quite a brief and clear definition to mitigative capacity as 'a country's ability to reduce anthropogenic greenhouse gas emissions or enhance natural sinks' (Winkler et al 2007, p. 694).

Regional greenhouse gas emissions were calculated by dividing national emissions across regions by using regional GDP as well as population. Furthermore, mitigative capacity is the mirror image of adaptive capacity on the emissions side (Yohe 2001). This report uses the same determinant categories. There are some indicators that are specifically different from adaptive capacity, mainly related to carbon sinks and mitigation policies.

Recognition of the necessity to mitigate, gathering knowledge of available options, and the ability to assess and implement the policies and measures are crucial for mitigative capacity. Similarly, technological ability and infrastructure affect the ability of societies to mitigate emissions.



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Origin of data: own calculations on the basis of the five adaptive capacity determinants

Capacity to adapt to climate change

- Highest capacity
- 2nd highest capacity
- Medium capacity
- 2nd lowest capacity
- Lowest capacity
- no data

Combined apadtive capacity expressed in quintiles.

Adaptive capacity calculated as weighted combination of economic capacity (weight 0.21), infrastructure capacity (0.16), technological capacity (0.23), knowledge and awareness (0.23) and institutional capacity (0.17). Weights are based on a Delphi survey of the ESPON Monitoring Committee.

Figure 21: Adaptive capacity of European regions in regard to climate change

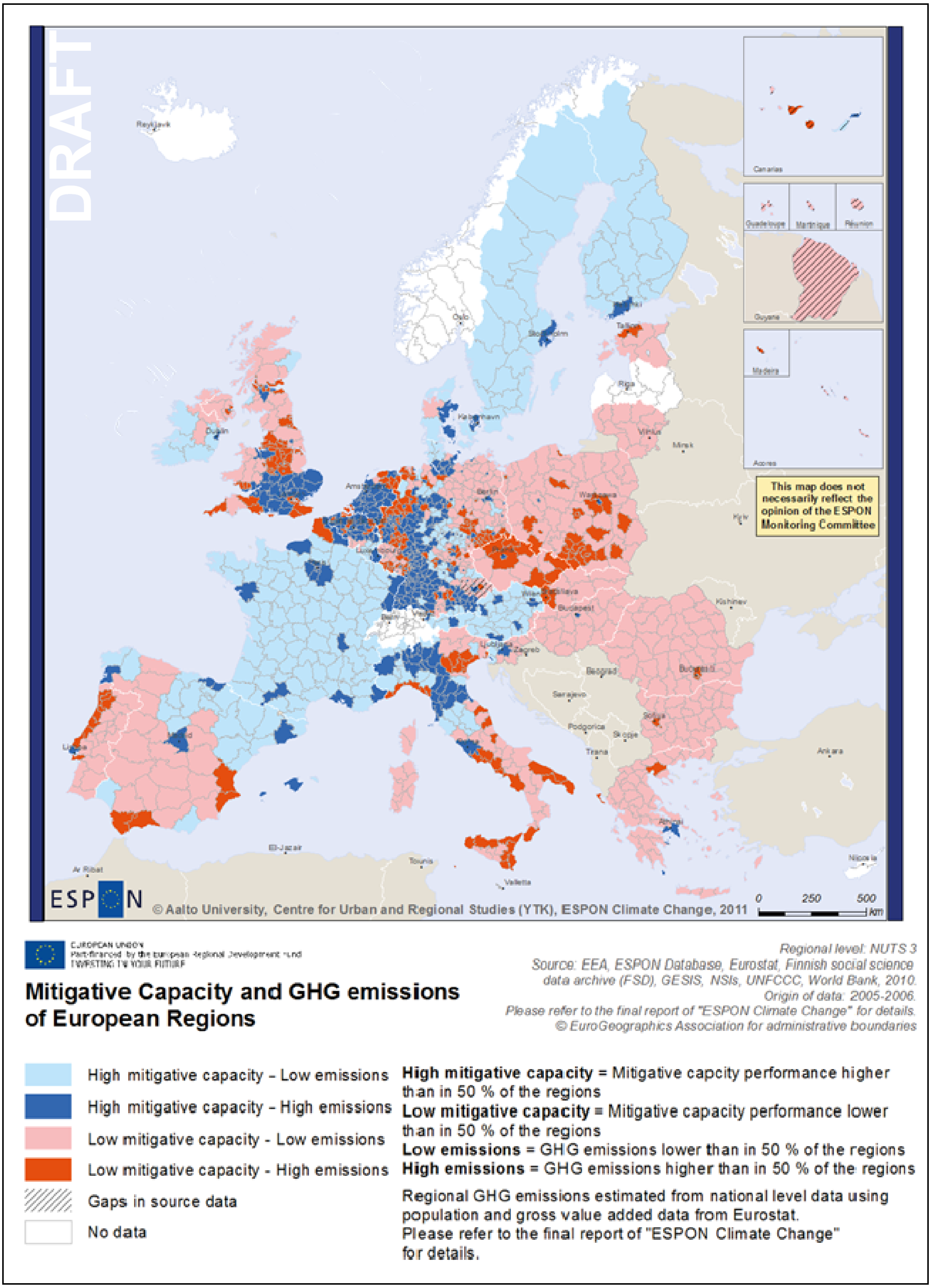

Figure 22: Mitigative capacity and greenhouse gas emissions of European regions

Regions that have low emissions and high mitigative capacity are mostly located in Northern parts of Europe, and parts of France and the Iberian Peninsula. Regions that have high emissions and high mitigative capacity can be found in Western Europe as well as in parts of Scandinavia. Regions that have low emissions and low mitigative capacity can mostly be found in Eastern Europe as well as in Scotland and Portugal. Regions that have high emissions and low mitigative capacity are of course the most crucial in terms of reduction of greenhouse gas emissions. These regions can be found in Eastern Europe, and in the UK Isles and Ireland. Also, some regions in Southern Italy fall into this category.

3.4.2 Response capacity of European regions

Tompkins and Adger have further explored the notion of response capacity in order to highlight the unnecessary dichotomy between mitigation and adaptation (Tompkins, Adger 2005). Tompkins and Adger consider that creating a false dichotomy between adaptation and mitigation slows down the response to the climate challenge. Rather, it is more useful to focus on the two together as part of the management of risk and resources in a society. Response, according to the authors, is defined as any actions that are taken by any region, nation, community or an individual to tackle or manage environmental change either before the change occurs or before the change has taken place (Tompkins, Adger 2005). In defining response capacity, the authors avoid an explicit reference to climate policy in order to emphasise the fact that there are also many other drivers of decision-making and that climate issues should not be analysed in isolation from wider developments in societies.

The authors identify two factors that drive response capacity, mainly the availability and penetration of new technology and willingness and capacity of society to change or adopt this new technology. Figure 23 displays these conceptual categories in relation to the indicators used in the ESPON Climate project.

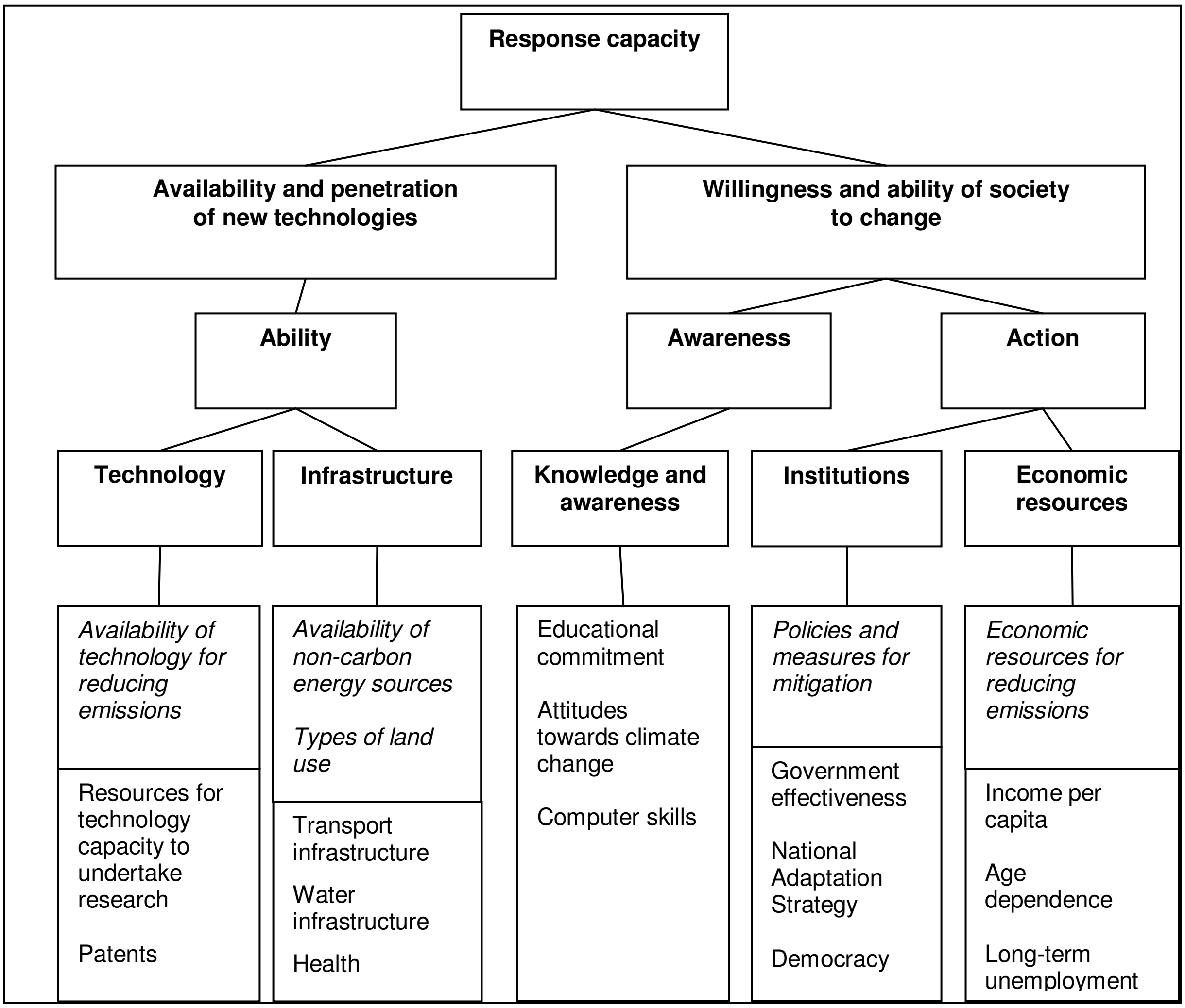

Figure 23. Indicators for climate change response capacity in ESPON Climate

Figure 24 shows that there are regions which have high or low potentials in both adaptive and mitigative capacity, but also that there are regions within which either mitigative or adaptive capacity is lower than the other. The differences between the types of regions have also implications to policy in terms of mitigation and adaptation. Building of mitigative and adaptive capacity is equally important, and can be in many cases complementary.

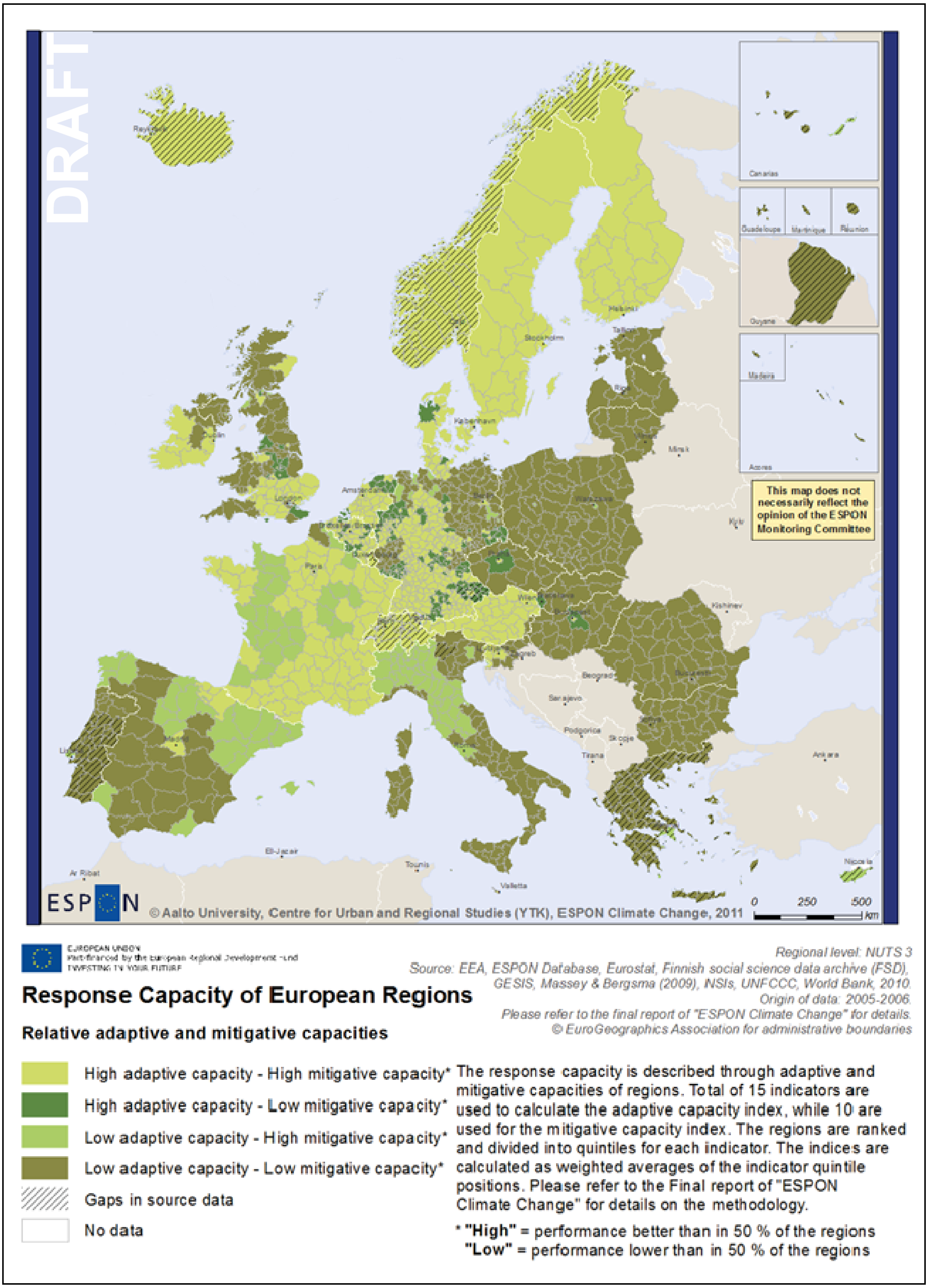

Figure 24: Response capacity of European regions in regard to climate change

3.5 A regional typology of climate change vulnerability

The IPCC defines vulnerability as "[t]he degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity (IPCC 2007c).

The potential vulnerability of Europe's regions to climate change (see Figure 25) looks slightly different compared with the map on aggregate impact: the south-north gradient which was already visible on the aggregate impact map is now much more obvious. This is due to the considerable adaptive capacity of Scandinavia and Western European countries which lowers the potential impact projected for these regions. However, this is somehow astonishing: particularly those countries which may expect a medium to high increase in impact seem to be less able to adapt than others for which the severity of the problem is less visible. In consequence, a medium to high increase of vulnerability may expect in the Mediterranean region, but also in South-East Europe.

This scenario for the future runs counter to territorial cohesion. Climate change would trigger a deepening of the existing socio-economic imbalances between the core of Europe and its Southern and South-eastern periphery. Particularly the East of Europe is also affected by demographic changes (in particular outmigration and ageing; see the following section), which may lead to an additional increase in sensitivity and therefore impact. At the same time these demographic changes would also decrease eastern Europe's adaptive capacity, since an ageing of population makes the population more sensitive (i. e. to heat) and less capable to adapt.

However, these problematic patterns of vulnerability call for additional efforts in balancing and harmonising differences to ensure a balanced and sustainable territorial development of the EU as whole, strengthening its economic competitiveness and capacity for growth while respecting the need to preserve its natural assets and ensuring social cohesion as stated by the Green Paper on Territorial Cohesion (EC 2008).

Apart from this remarkable result, territorially differentiated adaptation strategies seem to be important primarily for tourist resorts in the Mediterranean region, but also in the Alps, because both types of regions are identified as particularly vulnerable. Such differentiated strategies are discussed by two ESPON Climate case studies (see section 3.6). Moreover, agglomerations – mainly in the South - have to be mentioned. They are vulnerable for several reasons, of which urban heat might be the most relevant one from a long-term perspective as this poses not only risk for human health, but also leads to additional energy demand for cooling and as a second order effect possibly to frequent power failures.

These important observations and its policy implications are discussed in more detail by section 5.1 of this report.

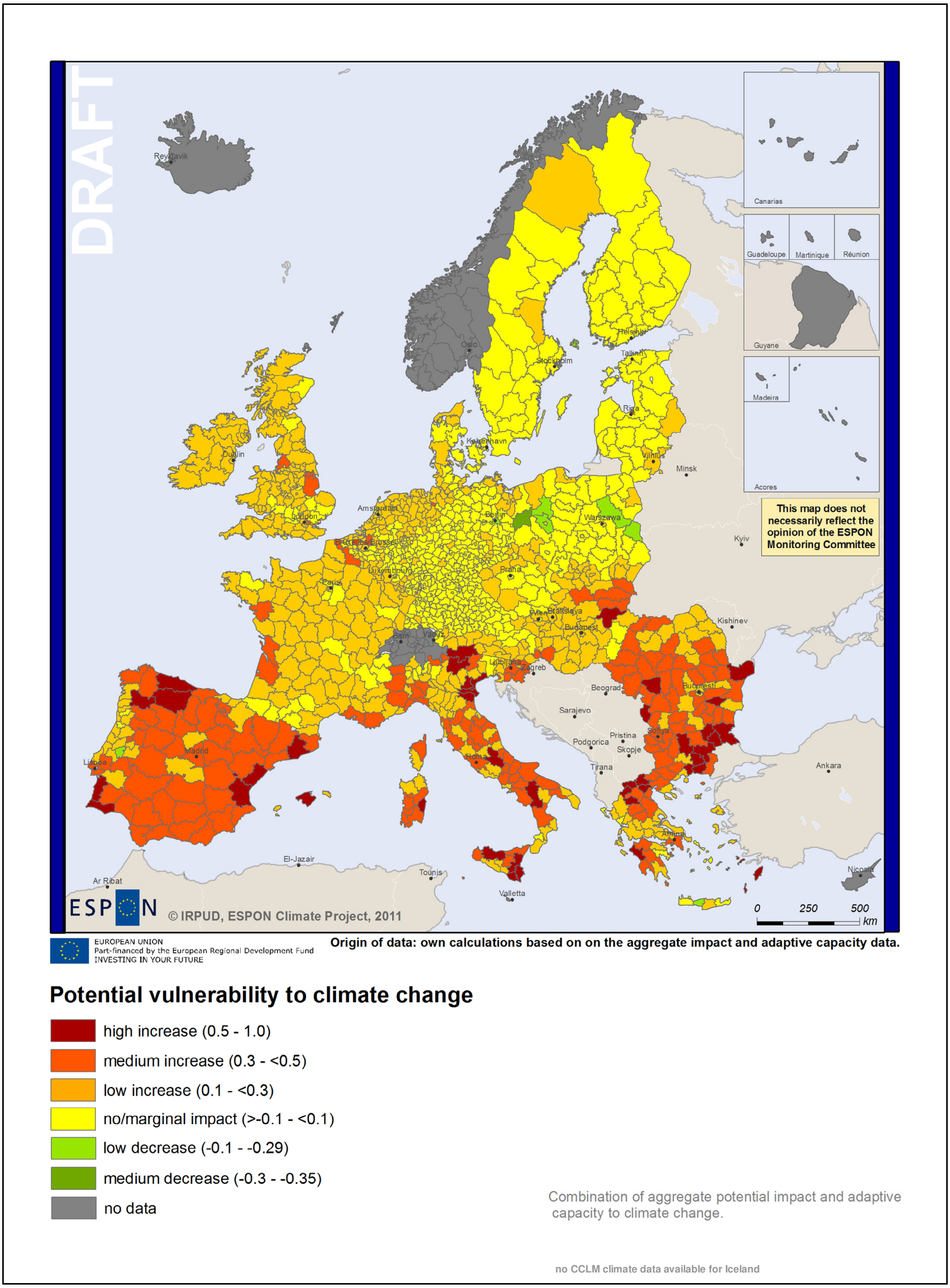

Figure 25: Potential vulnerability of European regions to climate change

Excursus: Future scenarios

Climate change will affect future regional development and vice versa. Thus, an analysis on effects of climate change should take into account not only future projections on exposure to climatic stimuli but also future sensitivity. However, such sensitivity projections would also raise considerable problems since, as already stated, both variables affect each other. Furthermore, economic, physical or social projections until the year 2100 are seldom, if at all, attempted. In any case such projections would be extremely uncertain given the complex hard to predict change mechanisms. On the other hand it is clear that solely considering future projections on climate change and comparing them with recent data on sensitivity neglects part of the story.

In light of these considerations the ESPON Climate project decided it was impossible or dubious to attempt fully-fledged alternative scenarios, but to rather address the issue of future alternatives as an excursus. Since for most indicators future projections are generally not available the following analysis focuses on demographic trends, because they are more predictable than other socio-economic processes and because the ESPON DEMIFER project could supply compatible demographic data up to the year 2100.

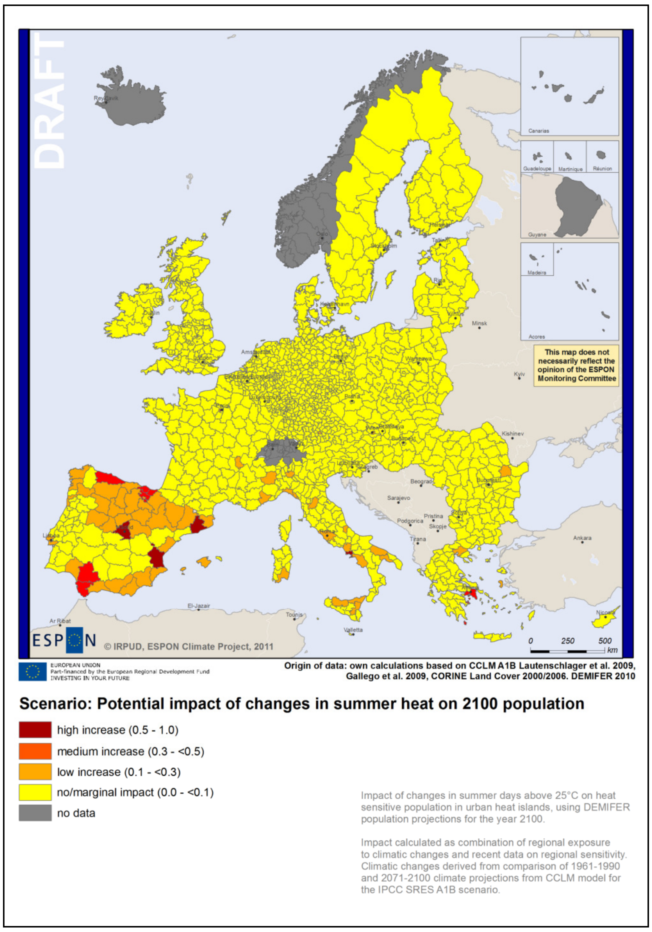

Figure 26: Impact of summer heat on 2100 population

Based on the DEMIFER data the potential impact of summer heat on sensitive population in the year 2100 was calculated. Based on the analysis of recent sensitive population in urban heat islands (i.e. senior people over 65 years old) future population in urban heat islands was derived and combined with projections on increases in the number of summer days. Of course this approach still holds the considerable limitation that recent (and not future) data on urban heat islands could be used which, again, illustrates the bottlenecks of such analyses.

The results of this analysis are quite plausible: impacts increase most significantly in Southern European regions. This is on the one hand of course a function of the increase in the number of summer days but also a result from an increasing number of old people rendering the situation even worse whereas most of the other regions do not show significant changes.

3.6 Case studies

The seven case studies of the ESPON Climate project serve to cross-check and deepen the findings of the pan-European assessment of the other research actions. They provide in-depth regional analyses of climate change vulnerability (exposure, sensitivity, impact, adaptation). The studies cross-check the indicators and findings of the European-wide analysis with the results of the case study areas, but also explore the diversity of response approaches to climate change. Finally, they develop conclusions for the implementation of measures at the European level.

Thus, the case studies need to integrate a twofold approach:

- An analytical approach coherent with the overall methodology of the project in order to ensure comparability among each other and connectibility with the overall analysis on the European scale;
- an explorative approach focusing on aspects not covered in the European-wide analysis, such as understanding the cultural and institutional factors influencing climate change effects on different European regions, and aspects peculiar to the respective case study area which can best be captured by the case study approach. In addition each case study explores certain dimensions of exposure, sensitivity and adaptation to climate change of particular relevance to it.

Seven case studies were identified which cover all five types of climate change regions identified in the exposure cluster analysis as explained by the following table:

Table 1: Case studies and selection criteria

Case study area	**ESPON three-level approach***	**Geographic coverage**			**Climate change regions**
		Macro-geographic regions	**Geomor-phological character**	**INTER-REG IVB cooperation areas**	
Alpine space	transnational	Central and southern Europe	mountain area	Alpine Space, Mediterra-nean, South Eastern Europe	Northern Europe Northern-central Europe, Southern-central Europe
Tisza river	trans-national	Central & Eastern Europe	river basin	Central Europe, South East Europe	Northern-central Europe, Southern-central Europe
North Rhine-Westphalia	regional	Germany (Western Europe)	river basin, hilly land	North West Europe	North western Europe, Northern-central Europe, Southern-central Europe
Coastal Mediterranean Spain, Balearic Islands	regional	Southern Europe	coastal area	Western Mediterranean, South West Europe	Mediterranean region
Bergen	local	Norway (Northern Europe)	coastal area, mountain area	North Sea Region	Northern Europe
The Netherlands	national	Western Europe	coastal area, river basin, lowlands	North Sea Region, North West Europe	North western Europe
Coastal Zone Aquifers	transnational	Finland, the Netherlands, United Kingdom, Spain, Romania	coastal area, lowlands	Baltic Sea Region, North West Europe, Western Mediterranean, South East Europe	All climate change types covered

3.6.1 Case study Alpine Space

Within the last 200 years both summer and winter tourism emerged as core economic sectors within the Alpine countries. After the Mediterranean region the Alps are the second most favoured holiday destination in Europe. With 60 million overnight guests tourism is the most important economic sector in most rural and alpine regions in the European Alps. At the same time tourism in the Alpine region is one of the economic sectors most affected by climate change.

The case study aimed at an in-depth analysis of impacts of the different climatic stimuli on Alpine tourism, of the specific sensitivity of Alpine tourism and the adaptive capacity of the tourism sector. The main focus was on the institutional and cultural dimension of vulnerability. For the adaptive capacity assessment of the tourism sector a specific set of indicators for assessing adaptive capacity was developed and a standardized survey was conducted among representatives of public authorities and non-state organizations in all Alpine states. The case study therefore complements the pan-European vulnerability assessment conducted in ESPON Climate with a qualitative approach by integrating qualitative data into the indicator based overall methodology.

The results of the vulnerability assessment of Alpine tourism give a better understanding of the impacts of climate change on the tourism sector and the adaptive capacity of the studied tourism regions in the European Alps. The expected effects of changing climate stimuli on the tourism industry can be differentiated along the altitude of the European Alps: for high alpine summer tourism the increase in mean temperature and the number of summer days are expected to have a positive effect due to the freshness of summer resorts whereas for high alpine winter tourism a decreasing attractiveness of snow sport activities is expected because of a decrease in days with snow cover, shortening of the touristic season and an increasing occurrence of natural hazards. Rural tourism in lower mountain areas is expected to benefit in summer as a result of an increasing attractiveness of the lake regions. In winter medium and low lying tourism destinations are expected to experience a significant decrease in snow reliability and length of season. In the lowlands of the European Alps especially city tourism will gain attractiveness due to a prolonged season and an increasing number of summer days.

Concerning the adaptive capacity of the tourism sector there are two fields of actions for enhancing the adaptation of tourism activities to climate change impacts across all Alpine regions: the informational basis available for decision-makers and the climate change awareness among tourism actors. In order to achieve well-informed decisions on adaptation activities in tourism regions and to develop consistent and long-term strategies, region specific climate data as well as impact and vulnerability assessments are needed. Additionally, this information has to be made available for decision makers in the tourism sector. The second field of action concerns the problem awareness among actors as a precondition for realizing adaptation options and reducing vulnerability. The study shows that major efforts need to be made in the field of awareness raising and capacity building within the tourism sector. This includes actors from the tourism economy as well as local providers, local populations and guests.

3.6.2 Case study Tisza river basin

The river Tisza has the largest catchment area among the tributaries of the river Danube. It covers nearly 160 thousand km^2 and has about 14 million inhabitants. Extreme weather phenomena are already a serious problem in the region. According to the forecasts, the frequency of extreme weather events in the context of droughts and excess waters (floods) is expected to increase as a result of climate change. A vulnerability study was carried out in the field of agriculture, using a uniform methodology. As there were no consistent data for the exposure index, no vulnerability calculations could be made regarding the impacts of floods, only a partial sensitivity analysis could be made. The impact of climate change on discharges and the uncertainties of forecasts are described in a special chapter of the case study report.

In the vulnerability analysis of the region's agriculture the quantitative change of summer and winter precipitation and the increasing number of summer days were taken as exposure indicators form the CCLM study. The magnitude and spatial pattern of the change of the quantity of winter precipitation correspond with earlier scientific literature (e.g. Clavier project). Sensitivity was analysed by means of six indices in three dimensions (environmental, social and economic).

Table 2: Sensitivity dimensions and indicators of the case study

Environmental	Social	Economic
Share of agricultural area (arable land, vineyard and orchard)	Number of private holding	Share of agricultural GVA on total GVA
Soil properties in terms of crop production sensitivity to drying climate		Share of agricultural employment on total employment
Soil properties in terms of crop production sensitivity to drying climate		

Indicators of adaptive capacity characterise the social and economic as well as infrastructure conditions, showing how they are capable of coping with unfavourable changes. Vulnerability was calculated on the basis of potential impact and aggregated adaptive capacity. The ultimate result of the vulnerability analysis proved the results obtained in the three partial analyses (exposure, sensitivity and adaptive capacity), namely, that in the water catchment area of the Tisza the most vulnerable are the counties in the plains and hills in Romania. As regards the impact of climate change on floods the sensitivity assessment was made using three indexes. Although the most sensitive areas were found to be on the downstream section of the Tisza, according to the analysis on the European scale and the literature available, the most negative impacts are to be felt on the upstream section of the Tisza and its tributaries.

The adaptability to the unfavourable impacts of the more and more extreme weather (warming and drying climate, excess water and flood) can be enhanced in the region by means of adapting land use structures; more effective possibilities of water retention and discharge regulation; promoting the policies in support of the above, with special regard to the distribution of domestic and EU resources of sustainable agriculture, forest and environmental management as well as water management and flood control; joint elaboration of transnational plans of water and land management.

3.6.3 Case Study North Rhine-Westphalia

The federal state of North Rhine-Westphalia (NRW) is situated in the north-west of Germany, comprising 396 municipalities (LAU2) and 54 NUTS 3 regions. Regional characteristics are diverse in terms of climate and geomorphology as well as in socio-economic structure. NRW is the most populous and the most densely populated state in Germany and contributes more than 20 % to the overall German GDP. Thus, possible adverse impacts of climate change may have severe consequences in reducing the overall economic performance of Germany.

Sensitivity towards climatic changes is expressed considering the physical, environmental, social and economic dimensions by means of a multitude of indicators. These are assigned to distinct direct (climatic variables derived from the regional model CCLM) and indirect exposure variables (frequency of flood events) representing changes from 1961-1990 to 2071-2100 under the emission scenario A1B. Sensitivity is expressed as a relative measure covering the range of values within the municipalities of NRW. It also takes into account the relevance of the respective sector for the municipality and is described by its current status. All indicators as well as the components of the vulnerability concept have been assigned equal weight in the aggregation process to enhance the interpretation of the results.

The multiplication of sensitivity with the expected exposure indicates the potential impacts. Also positive impacts are considered, which mainly stem from decreases in extreme days over some regions. Most adverse impacts are apparent in the Rhine valley and mountainous areas. This is mainly due to heat stress and flood danger in the valleys and increasing wind throw and forest fire danger in the higher elevated areas.

The generic adaptive capacity is expressed by the available private and public economic resources as well as the level of knowledge and awareness. The latter comprises the educational background and the commitment in terms of local initiatives related to sustainability or climate change. This indicator shows a more heterogeneous spatial pattern with highest adaptive capacities in the upper Rhine valley and university towns and lower values in the Ruhr area and low mountain ranges.

The relative vulnerability comprises the adaptive capacity and potential impacts. Less vulnerable municipalities are found for large part of the lowlands. For the other parts, however, the pattern is more heterogeneous, mainly caused by the spatially distributed values of the adaptive capacity. By and large, most vulnerable municipalities are situated along the upper Rhine valley, the Ruhr area in the mountainous areas as well as at the foothill of the mountains.

The focus of current adaptation strategies of NRW on urban areas is to some extent in line with our results, which show higher potential impacts in these areas. However, adaptive capacity with regard to knowledge and awareness and economic resources is generally higher in the urban municipalities, leading to a lower vulnerability. It has also been shown, that high potential impacts occur in the mountainous regions as well as along the foothills of the mountains. These municipalities should thus be investigated further with regard to their adaptation potential. Given new scientific findings and the discrepancy in risk level concerning inundation, current adaptation to flooding should be re-evaluated in NRW.

3.6.4 Case Study Spanish Mediterranean coast

The Mediterranean coast, together with the Balearic Islands, is the most important tourist area of Spain and a key pillar of the Spanish economy. Climate is a fundamental constituent, and perhaps the key influencing factor in explaining the attractiveness of this area for domestic and international tourists. According to the latest IPCC report (2007), average temperatures in the Mediterranean basin may increase substantially during the 21^{st} century while precipitation may decrease thus limiting the amount of water available for human and non-human uses.

The objective of this case study was to perform a vulnerability assessment to possible water shortages induced by climate change in the tourist areas of the Spanish Mediterranean coast. In order to produce such an assessment the study used variables related to exposure (water availability after changes in temperature and precipitation); sensitivity (characteristics of the tourist sector), and adaptive capacity (water supply alternatives, income). The relative weighing of each variable has been determined from a Delphi panel composed by ESPON experts.

Results show a distinct spatial pattern according to the combined dimensions of exposure, sensitivity and adaptive capacity. Generally, vulnerability tends to increase from North to South, mainly because of increasing exposure and decrease in adaptive capacity (especially concerning income) along this gradient. One extreme case is the Costa del Sol tourist area (one of the most important not only of Spain but of the entire Mediterranean) where scores for exposure, sensitivity and adaptive capacity combine to produce the highest vulnerability of the study area. At the opposite side, certain areas of Catalonia observe low vulnerabilities after a combination of low exposure and high adaptive capacity. Another interesting case are the Balearic Islands which rank low in exposure but medium to high in sensitivity thus indicating the strategic importance of tourism for the economy of the archipelago. Adaptive capacity, however, is in principle high enough to offset sensitivity. Hence, the resulting vulnerability is low.

The variables selected and the method chosen may be useful for other tourist areas of the Mediterranean coast. Generally, one could assume an increase in the vulnerability of Mediterranean tourist areas along a gradient West-East due to increasing exposure, perhaps medium to high sensitivity (due to the enormous growth of the tourist industry in certain areas such as the Balkans or the Eastern coasts), and low to medium adaptive capacities which may change in the future if alternatives such as desalination (already present and growing in many Mediterranean countries) can be implemented. However, sound adaptive capacities should move towards better water demand management (to an important extent only possible through the management of urban-tourist growth). However and as seen in the case of Spain, this alternative is still in its infancy.

3.6.5 Case Study Bergen

Due to Bergen's location in Norway its climate is characterized by cool temperatures and large quantities of precipitation: The annual precipitation reaches up to 5,000 mm in some areas of the Bergen city region – and is still expected to increase according to the latest climate change scenarios for the region, especially in autumn and winter. More importantly, the number of days with heavy rainfall is expected to double, thus increasing the likelihood of river flooding and landslides. In addition, due to rising temperatures worldwide the sea level in Bergen is estimated to increase by 75 cm by the year 2100, but will even increase up to 221-276 cm during storm surges.

Sensitivity to climate change can be measured by how different exposure indicators lead to a detectable change (positive or negative) in the studied object. In the Bergen case study the main sensitivity dimensions are physical sensitivity (infrastructure), cultural sensitivity (world heritage sites) and economic sensitivity (business activities and tourism). The potential impacts are a function of exposure and sensitivity, and regions can be both adversely and beneficially affected. For the Bergen region and Western Norway temperature increase, precipitation and sea level rise are the most important exposure indicators.

The greatest impact of climate change will be caused by the expected sea level rise and subsequent heightened exposure to coastal storm surges. If the estimated sea level rise of 75 cm in 2100 and the expected storm surge rise up to 2.37 metre will overflow buildings related to settlements and industries, historical sites, quays and port facilities, fish farming, roads and transport systems, sewage systems and wetlands. The effects of sea level rise will be most harmful in the central city area. Large part of the business area is located at the waterfront where also new settlements are developed.

A modified cost benefit analysis for sea level rise focussed on a range of adaptation measures. In the exercise the benefits are the reduced damages caused by the adaptation measure, and the aggregated costs have been measured by the expenses of the Norwegian Natural Damage Fund. Benefits are extremely hard to measure not only by using insurance values for buildings, but particularly for cultural heritage. Assessing costs of infrastructure is also difficult since some infrastructure will be replaced irrespective of any climate change through ordinary maintenance and improvement. In all exercises the cost exceeded the benefits which indicate that the adaptation measures should not be carried out. This probably tells us that benefits were underestimated and it also clearly illustrates the large problem of carrying out even a modified CBA in the Bergen case.

The adaptive capacity to deal with climate problems is considered to be fairly high in Bergen. The city has well educated inhabitants, a high score on computer literacy, and an active policy towards climate change and adaptation.

Some of the experiences from Bergen may be possible to transfer to other regions. It could be either knowledge of specific adaptation measures or of adaptation processes. Specific measurements towards sea level rise can for instance be relevant for other coastal cities in Europe. Likewise can knowledge of processes and tools used in adaptation policies be useful for other regions regardless of what measures that have been taken. This could include regional governance related to climate change adaptation and successful ways of involving relevant stakeholders in adaptation strategies.

3.6.6 Case study on the Netherlands

The increase of flood hazard, drought and water nuisance are recognized as the biggest challenges of the Netherlands with respect to climate change (V&W 2009). This case study focuses on flood hazards, expected to increase due to both sea level rise and an increase in extreme discharges of the main rivers.

The most recent projections on sea level rise for the Netherlands cover a range of 35 to 85 centimetres for 2100 (KNMI 2006). In the case of high-end/worst-case estimates, the rise is between 130 and 150 centimetres (Deltacommissie 2008). At the end of this century the 1:1250 per year discharge of the river Rhine at the Dutch border is estimated to increase by 15-35% (Klijn, Kwadijk et al. 2010). 56% of the Dutch area, where almost 70% of the population is concentrated, is prone to flooding. Yet even in the most extreme imaginable circumstances only 34% of the area, inhabited by 37% of the Dutch population, is expected to be exposed to flooding (Kolen and Geerts 2006). Due to the more simplified DIVA approach to coastal flooding, used in the ESPON framework, the estimated hazard along the coast is far more extensive than expected on the basis of more realistic flood models.

The sensitivity to flooding is assessed on the base of five impact dimensions: a) physical - settlement, power plants, infrastructure; b) social – inhabitants, elderly and low educated people; c) cultural – national landscapes, historic towns and UNESCO world heritage; d) economic – jobs, livestock and farming; e) environmental – NATURA 2000 areas.

The individual dimensions show different spatial sensitivity patterns. If merged into one sensitivity indicator the spatial pattern almost fully mirrors the potential exposure pattern. The combination of exposure and sensitivity shows a potential high impact in NUTS 3 regions located along the coast or close to the coastal area and, due to their expected extreme high exposure, in the Lake Ijsselmeer polders. On the municipality level these patterns are more differentiated due to the higher resolution and the dominant effect on the classification of one single municipality with an estimated extreme high potential exposure.

In line with the ESPON approach, the estimation of the adaptive capacity is based on generic features: percentage of graduated inhabitants, computer use, highway density, GDP and age distribution on the municipality level. Merging these indicators by averaging shows hardly any differentiation at this level. Therefore the final merging of the adaptive capacity and the potential impact into a vulnerability map on the municipality level resembles the potential impact map, but with a more smoothed pattern due to the almost uniform distribution of the adaptive capacity over the Dutch municipalities. Therefore the final classification is still to a high degree determined by the extreme exposure estimation of one single municipality.

With respect to flooding the analysis shows a high sensitivity to the used hazard assessment method. Two hazard maps were compared, one containing maximum water depths for flooding, irrespective of climate change and a second one taking climate change into account. In the non-climate change map the Netherlands appear to be less sensitive towards flooding, irrespective of the used spatial scale (NUTS 3 or municipalities), which might be based on methodological differences.

3.6.7 Coastal aquifers

Freshwater is one of the most important natural resources for life. Water resources and water supply belongs to the critical infrastructure in a society and needs special protection. The aquifers in Europe are unequal concerning their size, location and sensitivity to changes. Small, low-lying aquifers close to settlements, rivers and the sea shore are highly vulnerable to changes of all kind, including the potential impacts of climate change.

The case study on coastal aquifers was aiming to test the ESPON Climate model generated by the ESPON Climate project at the European level in the coastal aquifers of Europe. Low-lying shallow groundwater aquifers located on the Baltic Sea (Finland), the North Sea (Norway and the Netherlands), the Mediterranean (Spain), the Atlantic Ocean (Scotland) and the Black Sea (Bulgaria) were selected for further studies.

By developing the conceptual model for southern Finland coastal areas, it was possible to review the climate change introduced effects to the coastal aquifers. Eight out of ten pre-defined pan-European exposure indicators are relevant or important in the context of coastal aquifers.

The ESPON Climate project had suggested several sensitivity indicators for five sensitivity dimensions: physical, environmental, social, cultural and economic sensitivity. Three of the suggested pan-European indicators were applicable directly for the case study on coastal aquifers. The pan-European indicator ‘Settlements prone to coastal flooding’ was selected to indicate physical sensitivity. In addition, to better estimate the physical sensitivity of coastal aquifers, two case study-specific indicators were defined: ‘Water intakes prone to flash floods’ and ‘Water intakes prone to coastal flooding’. Both flash floods and sea level rise may negatively affect the coastal aquifers. Deterioration of water quality may have critical effects on water supply infrastructure. The pan-European indicator ‘Coastal areas prone to coastal flooding’ was selected to indicate the environmental sensitivity, and a new case study-specific indicator ‘Percentage of the groundwater yield from coastal aquifers’ was also developed. The latter indicator reveals how critical the coastal aquifers are for the region. The pan-European indicator ‘Coastal population prone to coastal flooding’ reflects the social sensitivity. A new indicator ‘Drinking water prices in coastal area’ was defined for economic sensitivity by comparing the yearly price of threatened coastal water supply with regional GDP.

As the best suitable pan-European indicators to describe adaptive capacity were chosen: ‘Resources for technology’, ‘Capacity for research’, ‘Water infrastructure’ and ‘GDP per capita’. Two new indicators were also developed to describe the adaptive capacity in low-lying coastal aquifers: ‘Availability of alternative water sources’ and ‘National, regional and local climate change adaptation strategies’. These indicators show qualitatively how well the regions are prepared to climate change effects on coastal aquifers, i.e. with alternative water sources and in their adaptation strategies.

3.6.8 Cross-case analysis

All in all, the case studies proved the applicability of the conceptual framework. It was shown that this framework is flexible in terms of spatial scales and indicators for exposure, sensitivity and adaptive capacity. The seven case studies are very good examples that the new comprehensive ESPON approach meets the demands of spatial planning: a new, more complex picture of the patterns of vulnerability became visible and can therefore be seen as a step forward from pure sector-based studies towards are more comprehensive view on vulnerability.

The spatial patterns between the pan-European assessment and the case study assessments are quite similar when comparing e.g. the pan-European cluster analysis with the analysis conducted for the NRW study: its case study area is divided into the same three different climate change types although slightly different exposure indicators were chosen. However, particularly the more fine-grained case study on North Rhine-Westphalia, but also the Tisa river case study show a more differentiated picture in terms of impact, adaptive capacity and vulnerability than the results of the pan-European assessment for these areas. This is mainly due to the normalisation of data: the existing relative differences between the municipalities of the case study area are quite small compared with the differences across the whole continent; even those municipalities which are marked in red on the case study map are only moderately vulnerable from a pan-European perspective. Thus, the pan-European vulnerability map shows a more homogenous picture for North Rhine-Westphalia. This clearly underlines the scale-dependency of any vulnerability assessment. The Tisza river case study shows what an uncertainty analysis could look like. Each exposure indicator provided by the pan-European assessment was intensively validated by comparing them with available results from other studies and scientific literature which cover the case study area. This approach is principally useful for any vulnerability assessment on the regional and local level in order to reduce the inherent uncertainty in the models and indicators.

Institutional and cultural issues were only partly covered by the case studies mostly to the lack of adequate data, but also available resources. There was a particular focus on these topics in the Alpine study which was based on an extensive questionnaire survey. To conclude, a more qualitative approach is needed in order to understand the driving forces for institutional settings and related response strategies. All the case studies pointed out that adaptation has to be addressed in a more comprehensive way by spatial planning on the different spatial scales.

The results of the economic sensitivity assessment on tourism correspond almost completely with the results of the case study on coastal Mediterranean Spain: there is a gradient from the North to the South where both studies calculated the greatest potential impact and vulnerability. However, the case study results are much more fine-grained (LAU2) and reflect possible situations of “maladaptation” and therefore possible conflicts between mitigation and adaptation measures on the very local level to which national and regional strategies on climate change, at least for the case of Spain, have not responded adequately yet. Here, the added value of the case study approach becomes clearly visible which is also underlined by the in-depth study on coastal aquifers: each cause-effect chain from exposure to sensitivity, impact, adaptive capacity and vulnerability has to be studied in detail in order to create an evidence base for adaptation strategies. This was simply not possible on the pan-European level within the given time frame and budget restrictions. However, it clearly shows further research needs.

4. Policy Implications

4.1 Climate change and its implications for existing European policies

Describing the scale of the current economic crisis, *Europe 2020 Strategy* (2010, 5) states that, "[t]he steady gains in economic growth and job creation witnessed over the last decade have been wiped out – our GDP fell by 4% in 2009, our industrial production dropped back to the levels of the 1990s and 23 million people - or 10% of our active population - are now unemployed". Responding to this requires effective policy initiatives and actions at the European, national, regional and local levels as well as across different policy sectors. This sub-chapter outlines some of the key implications of climate change for the EU competiveness and cohesion policy (4.1.1) and other EU policies and programmes (4.1.2).

4.1.1 Implications for competitiveness and cohesion policy

Competitiveness

Regarding climate change mitigation the EU has already set up a number of energy goals[1] aimed at reducing greenhouse gas emissions while increasing energy security. Since the adoption of the *Lisbon Strategy* the EU's overarching competiveness agenda has been to make the EU into the world's most competitive knowledge-based economy. The European Council adopted the *Europe 2020 Strategy* in 2010 to provide a route map for recovery of the current financial crisis. Crucially, the Strategy recognises that "strong dependence on fossil fuels such as oil and inefficient use of raw materials expose" Europe's consumers and businesses to "harmful and costly price shocks" and threatens Europe's "economic security" while also "contributing to climate change" (ibid., 6). It therefore puts forward three mutually reinforcing priorities of (ibid., 3): Smart growth, sustainable growth and inclusive growth. It goes on to identifine seven flagship initiatives, one of which is "Resource efficient Europe" which implies: decoupling of economic growth from the use of resources; shifting towards a low carbon economy; increasing the use of renewable energy sources; modernising the transport sector, and promoting energy efficiency (ibid., 4). All of these will contribute not only to climate change mitigation but also to future competitiveness of the EU. As part of its "smart, sustainable and inclusive growth" agenda, *Europe 2020* emphasises the need for improving resource efficiency to limit emissions as well as to "save money and boost economic growth". The future competitiveness of the EU depends on an adequate supply of energy and resources. Hence, it is paramount that the EU member states meet their energy goals which could result in "€ 60 billion less in oil and gas imports by 2020". Further progress with the integration of the European energy market is also needed, which could add "an extra 0.6% to 0.8% GDP". On top of that, meeting the EU's objective of 20% renewable energy sources has the potential "to create more than 600.000 jobs in the EU" with an extra "1 million new jobs" if the 20% target on energy efficiency is also met (ibid, 13).

The EU-15 is on track to meet its Kyoto Protocol target of reducing average emissions in 2008–2012 to 8% below 1990 levels. Assuming full implementation of EU legislation, the EU-27

[1] To reduce GHG emissions to 20% below 1990 levels by 2020; to increase the share of renewable energy to 20% by 2020; and to achieve 20% energy efficiency by 2020.

should likewise achieve its goal of cutting emissions by 20% by 2020. However, national pledges are under the 2009 Copenhagen targets.

The ESPON Climate project has shown a highly differentiated picture with regard to the mitigative capacity of different parts of Europe. The eastern and southern regions of Europe have a much lower mitigative capacity than the northern European regions. These former are the regions which are already performing less strongly with regard to the EU competitiveness indicators. A low capacity for mitigation implies vulnerability to fluctuations to energy cost and security and as a result a negative impact on competitiveness. The Commission acknowledges the disparities in mitigative capacity and its crucial role in the future competitiveness of Europe and it intends to pursue a number of other initiatives by 2011 (EEA 2010). While these measures are aimed at further reducing greenhouse gases in the EU, they do not seem to take into account the significant differences in the mitigative capacity of different European regions and their ability to meet the EU-wide targets. A significant part of the EU-wide attempts to reduce greenhouse gas emissions need to focus on enhancing the mitigative capacities of the peripheral regions.

Even if all the aforementioned initiatives succeed in reducing greenhouse gas emissions to the targeted levels, there is a need to adapt the EU's economic competiveness because ongoing climatic changes. While the estimated cost of adaptation for Europe ranges from € 2.5–16 billion per year for the infrastructure and coastal defence (UNFCCC 2007) to € 4–60 billion per year for infrastructure (Stern, 2007), it is widely acknowledged that the cost of addressing climate change now is lower than the costs of inaction (OECD 2009). An important step taken by the EU is the adoption of the EU *White Paper on Adaptation to Climate Change* in 2009 which proposes a framework for action based on developing the knowledge base and integrating adaptation into EU policies through increasing overall resilience.

The Commission also adopted a communication on disaster risk prevention in 2009, which aims to integrate related risk policies and instruments. Such strategies to adapt to climate change are necessary to manage impacts and the Commission plans to pursue a number of other initiatives by 2011 (EEA 2010). At the level of the EU as whole, compared with other major economic regions in the world, Europe will be less affected by climate change (e.g. IPCC 2007 report). This is particularly the case for the economic core of Europe which also has, as shown in the ESPON Climate project, a high level of mitigative and adaptive capacity. If this capacity is capitalized, it will certainly enhance the competitiveness of the EU in the global market. Another important point is that the diversity of climatic regions in Europe allows for a degree of economic adjustments. For example the economic sensitivity analysis of the ESPON Climate project suggests that while the impact of climate change on summer tourism is negative in the Mediterranean regions, it is positive in the colder regions of the north which will benefit from a more favourable Tourist Comfort Index. For the competitiveness of the EU as a whole, this implies that a potential loss of tourism in one part of Europe may be compensated by a potential gain in another part. Furthermore, climate mitigation and energy efficiency policies are one of the four key priorities of the renewed Lisbon Strategy. This means that through the development of its knowledge base and support for research and innovation, EU action on climate change can converge with the Lisbon Strategy. Nevertheless, without effective adaptation measures such transformations may lead to increased disparities in Europe.

Cohesion

While climate change will affect Europe as a whole, the severity of its impacts varies in different regions and for different economic sectors and social groups. The Impact Assessment of the EU White Paper (EC 2009) on adaptation states that, "[a]daptive capacity is often positively correlated with economic development, thus access to efficient adaptation is greater for high-income groups and richer areas, and less for the poor, and such effects are often compounded by levels of awareness and access to information (as well as insurance)". The report adds that "more adverse impacts may be expected in some regions with lower economic development" (ibid.,16-17). This assumption was clearly proved by the ESPON Climate project: particularly large parts of Eastern Europe, but also the Mediterranean region are characterised by a low adaptive capacity. Considering the fact that these regions are from today's perspective predominantly less developed than the centre of Europe, the existing imbalance between the centre and the periphery of the European Union may be depended due to the projected impact of climate change.

The results of the ESPON Climate project shows that the following sectors of the economy are directly affected: the primary sector (agriculture, forestry), tourism (winter and summer) and the energy sector (supply and demand). The severity and nature of impact on these sectors vary in different parts of Europe resulting in negative impacts in some places (mainly Southern and South-Eastern Europe) and positive impacts in others (i. e. Scandinavia). Also, depending on the share of these sectors in the overall economy of different regions, the expected impacts can be more or less damaging economically (in terms of GVA) and socially (in terms of employment). It is evident from the economic impact analysis that the primary sector in the peripheral regions is particularly vulnerable to climate change. This plus a low level of adaptive capacity may exacerbate regional disparities in Europe and reduce European cohesion. Hence, there needs to be a mainstreaming of climate issues e.g. into the EU's rural development policy in the interest of a balanced territorial development of European rural areas. Such mainstreaming is also required under the Renewed Social Agenda (COM (412) of 2 July 2008) which is based on a holistic approach to social policy. On the other hand, some climate change impacts can provide opportunities which, if capitalized, can reduce such disparities in Europe (see section 4.2). Overall, there is a need for oversight and responsibility at the EU level to complement the actions at national level to ensure cohesion under the auspices of climate change.

The Fifth Cohesion Report (5CR), published in November 2010 for comments (EC 2010), is the first report which is adopted under the Lisbon Treaty. It confirms that "[t]he growing threat of climate change and the political goal to radically increase the share of renewable energy in the EU underlines the fact that policies at different levels will need to be coordinated to respond to these various threats and opportunities in an efficient and effective way and to avoid them counteracting each other" (op cit).

It is therefore important that EU policies on climate change take into account its varied impact on different localities in Europe, as mentioned above. The Cohesion Policy itself needs to pay attention to wider drivers of spatial inequality which cannot be determined by solely focusing on economic indicators such as GDP per capita. As the ESPON Climate project shows, a significant driver of potential future disparities is the degree of adaptive capacity for tackling climate change. This, however, as shown in this project is highly differentiated across Europe with peripheral regions in the east and south of Europe showing a low level of adaptive capacity. Therefore, attentions should be paid to the different level of efforts and investments needed to mitigate and adapt to climate change in different parts of Europe. Although the 5CR dedicates a chapter on 'Enhancing environmental sustainability' which acknowledges that climate change will hit southern and eastern Europe hardest, it says little about how these varied climate change impacts will be reflected in future cohesion policy. In fact, it continues to put the emphasis on economic indicators for providing financial support for the regions, stating that, "[a]s today, support would be differentiated between regions based on their level of economic development drawing a clear distinction between 'less' and 'more' developed regions" (EC 2010, 10). The findings from the ESPON Climate Project provides a robust basis for identifying the expected social and economic impacts of climate change on different regions and their adaptive capacity to cope with these. These should inform the allocation of EU funds so that regions that are expected to be hit severely and have low mitigative and adaptive capacity are provided with targeted financial assistance to enhance their capacities. The evidence provided by this project could be used to develop criteria for ERDF-funded projects (see below). For example, it could be a requirement that EU-funded infrastructures should demonstrate a high level of energy efficiency as well as adaptability to future climate change.

4.1.2 Implications for other EU policies and programmes

Transnational cooperation

In the period 2007-2013, four inter-regional, 13 trans-national and 52 trans-boundary programmes have been launched within the framework of the European Territorial Co-operation. In this study we focus on ten European trans-national regions and the INTERREG IVC Operative Programme covering the entire territory of the EU. The theme of climate change can be found in the operative programmes elaborated for each trans-national region, both in the analysis chapter and in the strategy (see Table 3). Climate change issues identified by current operational programmes which are relevant for regional development are: floods, forest fires, droughts, extreme weather conditions and events, as well as sea level rise. The mitigation of climate change impacts is indirectly addressed by these programmes as it appears as an intervention in the interest of achieving other priority goals. As a rule unfavourable impacts are addressed by the development of water management and the use of various means of risk prevention. As far as recommendations for concrete projects are concerned, tasks requiring international co-operation have been mentioned most frequently in, for example, development of models, development of forecast systems, transfer of knowledge, new methods of planning, development of the spatial and regional planning practice, and its preparation for coping with the impact of climate change, forecasting of and coping with the potential impacts of climate change and natural risks, and coping with trans-boundary risks. The emphasis is on the theme of water management. The results of the ESPON Climate project may support planning for the next programme period (2014-2020). On the maps presenting the expected impacts of climate change, the geographical differences and the relevance of the climate impacts can be identified for each trans-national region, and the regional importance of the relevant impacts can be ranked, helping thereby the identification of the territories requiring intervention, the regional goals and priorities and the description of the recommended projects. The maps on adaptive capacity can be the basis for describing the measures necessary for strengthening factors on adaptive ability.

Potential future cross border cooperation (INTERREG IVA) could enhance climate change mitigation and adaptation capacities. Especially in regard to climate change adaptation competition or contradicting adaptation in cross-border areas can be avoided. Due to the manifold INTERREG IVA areas the project has identified here only those border regions with strong differences in adaptive capacity and would especially recommend future strong cooperation in the border regions of: Germany and Poland, Germany and Czech Republic, Hungary and Austria, Austria and Czech Republic, Austria and Slovakia, Switzerland and Italy, France and Italy. The projects should be used as sources for direct support of further policy development. The overall structure of regional development projects could be enhanced towards delivery of policy recommendations, derived from practical examples of regional cooperation. Table 3 below gives an overview over current INTERREG IVB & C programmes and selected programme priorities. The table is structured in the following way: the 1st column lists the relevant INTERREG IVB and C programme areas. The 2nd column lists the climate change impacts identified by these programme areas. The 3rd column lists the climate change stimuli and impacts identified by the ESPON Climate project. The 4th column lists the existing relevant areas of intervention of climate change of the respective programme areas. Where the identified areas appear suitable for future programmes no changes are proposed. Those areas where the project identified a potential enhancement of the current programme suggestions are given in *italics*. The final 5th column lists potential criteria that could be included in further developments of the programmes. The INTERREG areas Acores-Madeira-Canarias; Caribbean and Indian Ocean could not be covered in this assessment because the used climate model does not cover these areas.

Other relevant EU policies and programmes are discussed in more detail in the extended scientific report.

Table 3: Climate change and INTERREG IVC Operative Programmes

Name of the transnational cooperation OP	Climate change issues identified by current operational programmes	Climate change stimuli and impacts affecting sectors (identified from ESPON Climate project)s	Relevant area of intervention, current and proposed.	Climate related criteria for further operational programme area development
Northern Periphery	Flood, sea level rise, extreme weather events	Flood, sea level rise	2.(i.)Environment as an asset in the periphery impact and possible implications of climate change and means to reduce it at a community level	Risk management for settlements potentially affected by river floods related to climate change
Baltic Sea	Flood, forest fire, extreme precipitation	storm surges, sea level rise, floods flash floods, Changing frost conditions, Changing precipitation patterns	3.1. Water management with special attention to challenges caused by increasing economic activities and climate changes. Actions, action plans, strategies and legislative frameworks for improved water management in order to minimise impacts of climate change 3.4. Integrated development of off-shore and coastal areas. Preparation of scenarios, adaptation strategies and intervention plans towards mitigation of impacts of climate change on coastal areas *Holistic approaches to identify impacts of climate and global change (including demographic changes), with a special focus on forestry and tourism*	Further development of regional adaptation strategies related for climate change impacts on forestry Climate change impact assessments on coastal and island areas, including tourism and water quality (algae blooming).
North West Europe	Flood, drought, forest fire, increasing frequency of natural hazard	Flood, sea level rise, river floods, flash floods, storm surges	2.2. To promote an innovative approach to risk management and prevention, in particular water management (effects of the high concentration of human activities in coastal areas and river valleys; impacts of sea level rise on coastal areas and flood risk; the marine environment) in the context of climate change *Holistic approaches to identify impacts of climate and global change (including demographic changes), with a special focus on heat islands, storms and infrastructure*	Combination of flood and storm surge prevention and spatial planning as cross border and transnational initiatives.
North Sea	Flood, sea level rise	Flood, sea level rise, river floods, flash flood, storm surges, storms, sea level rise	Adapting to and reducing risks posed to society and nature by a changing climate. Holistic approaches to identify impacts of climate and global change (including demographic changes), with a special focus on heat islands, storms and infrastructure	Combination of flood and storm surge prevention and spatial planning as cross border and transnational initiatives.
Atlantic Coast	Flood, sea level rise, forest fire (south)	Flood, sea level rise, river flood, flash flood, storm surge, storms, Sea level rise	2.4. Protect and promote natural spaces, water resources and coastal zones, *Focus on aspects of climate and global change, taking into account structural development of populated coastal areas and hinterlands.*	Development of regional strategies to anticipate the impact of river floods; Development of regional strategies to anticipate the impact of storms and storm surges
Alpine Space	Alpine hazards, Floods	Floods, Flash floods, Changes in precipitation / evaporation patterns	Climate change is affecting the Alps earlier and rather more severely than the rest of Europe. Coping with effects of climate change in all aspects (from changing river systems to changing cultural landscapes) will be a major challenge for the cooperation area (…) Holistic approaches to identify impacts of climate and global change (including demographic changes), with a special focus on future development scenarios, including tourism, agriculture, urban expansion and infrastructure.	Diversification of tourism, also interlinked with water scarcity; Integration of sustainable cross-border adaptation and mitigation concepts; Options of enhancing synergies to avoid conflicts (especially on adaptation measures); Over regional and transnational water management approaches, especially focusing on the Alps as a "water tower".
Central Europe	Floodrisk	Floods, flash floods, Changing frost conditions, Changing precipitation patterns, Increase in summer days and summer temperatures, Sea level rise	3.2. Reducing risks and impacts of natural and man-made hazards. Developing and applying tools and approaches for mitigation and management of the impacts of climate change and other risks	Development of regional climate change adaptation strategies on floods, heat waves, forest fires; Development of regional climate change adaptation strategies on water scarcity; Development of regional climate change adaptation strategies on tourism; Development of regional climate change adaptation strategies for agriculture and forestry
South West Europe	Hydrological risks and forest fires	Agriculture, forestry, flood, sea level rise	(… translated from Spanish…) Transnational planning to mitigate environmental challenges and risk (…) Objective 6: Impulse cooperation strategies to prevent natural risks, particularly forest fires. *Integration of, current and future, hazard and risk concepts into development plans; Holistic approaches to identify impacts of climate and global change (including demographic changes)*	Development of regional transnational climate change adaptation strategies on heat waves, water shortage and forest fires.
Mediterranean	Forest fires, droughts decreasing rainfall, hurricanes, floods, sea level rise, tidal waves, coastal erosion…) sea level rise	Storm surges, drought, floods, forest fires, changing precipitation patterns, changing evaporation patterns, iIncrease in summer days, sea level rise	… monitoring the consequences of climate changes; assessment of vulnerability of landscapes, forests and natural resources; monitoring of floods and fires; anticipation of risks related to sea level rise.. 2.4. Prevention and fight against natural risks within the European Union, the Med area is particularly exposed to natural risks (…) *Integration of, current and future, hazard and risk concepts into development plans; Holistic approaches to identify impacts of climate and global change (including demographic changes and migration)* *Strengthening of cross-border initiatives to prevent emerging risks*	Management of public (including tourism) water demand. Identification of possibilities to save water instead of relying on current water management schemes and further development of desalinisation plants; Avoidance of mal-adaptation, e.g. transferring costs and risks from water sector to energy sector; Management of land take (urban sprawl)
South East Europe	Drought, forest fires, floods, landslides	Flood, sea level rise, changing precipitation patterns, changing evaporation patterns, increase in summer days, sea level rise	2.1. Improve integrated water management and transnational flood risk prevention, *including climate change impacts* 2.2 Improve prevention of environmental risks, including impacts of climate and global changes, also focusing on demography and migration	Emphasize analysis and management concepts on impacts of climate change on forestry and agriculture; Development of common (cross-border) methodology for land use restructuring, including integrated water management planning
INTERREG IV C		INTERREG IV B covers all of Europe - no distincts climate change stimuli on this level	*Expansion of cooperation in all fields of analysis and concept development on climate and global change adaptation concepts.*	Exchange of experiences of different regions to foster on further development of best practices; Endorsement of cooperation concepts for GHG reduction

4.2 Policy options for climate change mitigation and adaptation

Europe plays an important role in global climate policy that aims to reach a global deal for emissions reductions and encourage the take up of adaptation. The EU's latest position on climate change mitigation was outlined in the Climate action and renewable energy package (EC 2008). The European Union has stated that its aims for emissions reductions are a 20 percent reduction of greenhouse gases by the year 2020. The second target of the Union is to increase the share of renewable energies to 20 percent in energy consumption by 2020. Adaptation, on the other hand, was initially considered a predominantly developing country issue due to their lower capacity and resources to adapt to changes. In the past five years adaptation has also become a policy goal in many European countries with the majority of European countries now having started or completed their national adaptation strategies (NAS). The EU, following national developments, published a white paper in 2009 that outlines the Union's approach to adaptation. It outlines the Union's approach to adaptation, which in the next two years focuses on accumulating knowledge and sharing that through a clearing house mechanism (EC 2007).

4.2.1 Options for adapting to climate change

The White Paper emphasises the need for a strategic approach, recognising that adaptation is already taking place across several member states. The White Paper complements the national initiatives that are taking place and aims to support international efforts of adaptation, also particularly in developing countries. It is stressed that action at the EU level is necessary, although most of the adaptation measures will be taken at the national, regional or local level.

Coordination of adaptation by the EU is considered to be important in order to avoid major gaps in trans-national linkages and to provide common strategic direction to achieve a coherent approach to adaptation within the Union (Ribeiro et al. 2009). There are existing tools that can be used to support the regions' development of regional adaptation strategies (RAS), the most important of which is funding from existing EU funding mechanisms. Activities that can be supported from the funds include knowledge development, testing and validation of knowledge development, monitoring of the RAS development, its implementation and generation of awareness amongst relevant stakeholders as well as amongst the general public (*Ibid.*). The existing mechanisms that can be used include the regional development, economic and social cohesion funds, such as the European Regional Development Fund (ERDF), The European Social Fund (ESF), LIFE + and INTERREG funding, for example.

RAS are a relatively recent development in Europe and there are even fewer studies of them than there are national adaptation strategies. Regions play an important role in terms of regulating issues related to the built environment, building and maintenance of infrastructure in terms of drainage and piped water, and provision of services, such as fire protection, public transportation and disaster response. The role of regions is not merely limited to the normal maintenance but should also include long-term maintenance, pre-disaster damage limitation, immediate disaster response and rebuilding (Gagnon-Lebrun, Agarwala 2006). Thus far, there have been a limited number of studies that have analysed the emergence and content of regional adaptation strategies, mainly due to the reasons that regional initiatives are even more recent than the national ones. Overall, the development of RAS is hindered by the uncertainties on the scale, timing and consequences of climate change, as well as lack of information, knowledge and expertise at the regional as well as local level (Ribeiro et al. 2009).

Although strategies have been pursued, it does not necessarily mean that all regional adaptation strategies include specific implementation measures that are already outlined in the strategy paper. Thus, the existence of a strategy does not necessarily guarantee action on adaptation. In their analysis of level of adaptation process of regional adaptation strategies, Ribeiro *et al.* have utilised the division made by Massey and Bergsma (2009). According to this division, policy actions can be divided into policy concerns, policy recommendations and policy measures. Many of the analysed RAS put forward general directions on how to respond to the climate challenge, expressing a level of concern. There are, however, strategies that explicitly put forward policy recommendations, particularly in relation to organising and informing the regional response, or setting up implementation bodies, and approximately half of the RAS analysed included these. Actual policy measures were put forward in less than 20 percent of the strategies (Ribeiro et al. 2009).

As one would expect, priority sectors in the adaptation strategies vary, according to which sectors are considered to be particularly vulnerable within a specific region. According to Ribeiro et al. two particular sectors stand out, namely health effects of climate change and landscape management in terms of flooding, sea level rise and drought. Regional emphasis on adaptation varies. Water supply and treatment, biodiversity management and food production and the agricultural sector were also popular foci of the examined regional adaptation strategies. In relation to the types of adaptation responses, 40 percent of the responses can be characterised as contributing to the reduction of risk and sensitivity (ibid.).

The potential for maladaptation across European regions also exists. According to Barnett and O'Neill (2010, 211) maladaptation is "action taken ostensibly to avoid or reduce vulnerability to climate change that impacts adversely on, or increases the vulnerability of other systems, sectors or social groups". 'Maladaptation' excludes sustainability in an integrated and long-term understanding; it is often connected to high-energy consumption and therefore implies that negative feedbacks exist between adaptation and mitigation. Examples comprise desalinisation, production of artificial snow and the increasing use of air conditioning.

Adaptation measures can target four different objectives: Building of adaptive capacity, reduction of risk and sensitivity, increase of coping capacity or capitalisation on climate change, (Massey & Bergsma 2009). For the most part, adaptation measures that reduce risk and increase coping capacity across the five impact dimensions relate to planning and supporting the emergency services. Measures to build adaptive capacity relate to the production of knowledge that can enable adaptation in the longer term. Finally, policies to capitalise on climate change are important but not many examples exist yet. For more details on specific impact dimensions and related adaptation measures, see the extended scientific report.

4.2.2 Options for mitigating climate change

The main aim of mitigation policy, and the ultimate objective of the UNFCCC as detailed in Article 2, is to achieve stabilisation of greenhouse gas (GHG) concentrations in the atmosphere that would prevent further anthropogenic interference with the climate system (Rogner et al. 2007). The EU re-established its position in terms of mitigation and climate policy in 2007, when the European Parliament adopted the resolution on climate change in February (Commission of the European Communities 2008). Furthermore, the agreement by the European council to set legally binding targets to reductions of emissions in March 2007 signalled the determined position to set a leading example in terms of global climate change mitigation policy. The European Commission put a comprehensive package of mitigation measures forward in 2008 with a focus on reducing emissions through emissions trading, increase in the use of renewable energy and the use of biofuels in transport.

In recent years, the European Environment Agency has compiled a list of policies and measures to mitigate climate change titled Climate Change Policies and Measures in Europe (PAM) (EEA 2010). The policies listed in the search engine have been collected from the UNFCCC National Communications that are in turn provided by the parties to the Convention, and other relevant sources. The policies and measures are detailed in terms of Member States, the type of policies adopted, the sector within which the policy is adopted, the status of the policy in terms of its implementation and the GHG that the measure tackles. Policies to mitigate climate change are divided into different types, ranging from regulatory instruments to voluntary agreements and educational measures. A total of 1223 policies have been listed in the database for EU 27 Member States, see Table 4. In terms of the types of policies the majority of them focus on regulatory measures, including for examples directives on energy efficiency and energy saving, and promotion of biofuels. The second popular measures for mitigating climate change are economic ones, such as sectoral development plans and the Emissions Trading Scheme. The remaining policy types are not as popular with education and research policies reported as the least used within the Member States.

Table 4: Number of climate change policies and measures in EU member states by type and status

		Number of policies by status				
Policy type	Number of policies	Implemented	Planned	Adopted	Expired	Other
Regulatory	382	238	93	47	4	-
Economic	311	213	48	26	22	2
Information	157	107	29	19	2	-
Fiscal	102	65	21	15	1	-
Planning	89	56	23	10	-	-
Voluntary/ negotiated agreement	80	52	19	6	3	-
Research	39	22	11	5	1	-
Education	37	28	4	3	2	-
Other	26	17	7	2	-	-
Total	**1223**	**798**	**255**	**133**	**35**	**2**

All the Member States (EU27) have policies related to climate change mitigation but the number of policies differs greatly, see Table 5. Belgium and the UK lead with the most policies, while some Eastern European countries have the least number of policies. Certainly for some countries, the low number of policies can be explained by the small size of the country but the difference between Belgium with over a hundred policies compared to that of Lithuania with 14 policies is fairly considerable.

The regional level is affected by policy initiatives on other levels of governance and this is also true with regards to mitigation. In addition to steering coming from other levels of governance, there are regions and local actors that have begun preparing their own strategies, developing their own guidelines regarding mitigation and adaptation.

Table 5: Number of climate change policies and measures in EU member states

Member State	Number of policies		Member State	Number of policies
Belgium	104		Italy	43
United Kingdom	92		Ireland	41
Germany	85		Czech Republic	36
Spain	69		Cyprus	28
Greece	65		Latvia	28
Denmark	64		Netherlands	28
France	63		Bulgaria	27
Estonia	53		Malta	24
Hungary	53		Slovenia	24
Poland	51		Romania	15
Portugal	51		Lithuania	14
Austria	50		Slovakia	13
Finland	49		Luxembourg	8
Sweden	45			
			EU 27	1223
Source: EEA, Climate change policies and measures in Europe, 2010				

The focus on territorial development and cohesion within the EU and mitigation of climate change are aspirations that have close linkages. In recent years the territorial focus within the EU has been realised through the Territorial Agenda in 2007, which strives towards sustainable territorial development across the Union. Sykes and Fischer (2009) are concerned about the role that transport will play in achieving the aims of the territorial policies in terms of creation of new economic zones or improving and increasing mobility across regions. According to the authors, reduction in greenhouse gases is going to prove difficult if no additional transport policy is introduced in addition to the Territorial Agenda. It is important that impacts of increased mobility and accessibility on emissions are understood. Another area where the Territorial Agenda and climate change mitigation efforts traverse is urban sprawl (ibid.). Davoudi also identifies concerns when discussing the demand of energy in terms of territorial policies, arguing that the territorial policies have been instrumental in managing energy demand through the implementation of land use policies. Of particular interest are also policies that focus on reducing car travel as well as policies that increase energy efficiency of the built environment (Davoudi 2009).

The territorial potentials for mitigation are determined by the underlying mitigative capacity of a society. Firstly, there are regions which have high mitigative capacity and low greenhouse gas emissions. Secondly, there are regions which have both high mitigative capacity and high levels of greenhouse gas emissions. Thirdly, there are regions which have low mitigative capacity and low greenhouse gas emissions and finally there are regions which have high emissions and low mitigative capacity. Although mitigation policies are very similar across countries, particularly those driven by the EU directives, there is scope for examining regions, their capacity and the policies that can target greenhouse gas emissions. The two types of regions, which are especially important, are regions, which have high emissions and high adaptive capacity, and regions, which have high emissions and low mitigative capacity. In both types of regions, it is clear that measures need to be undertaken to reduce emissions. In regions, which have high capacity, more efforts need to be placed on implementation of mitigation policies. It seems that these regions have the capacity to reduce emissions but emissions still are high. In areas with low mitigative capacity and high emissions, the emphasis can be placed on both increasing mitigative capacity in order to facilitate the development and uptake of cleaner technologies as well as implementation of policies to mitigate emissions.

4.2.3 Options for harnessing synergies between adaptation and mitigation

Although both mitigation and adaptation as policy responses to climate change have been developed for some time now, considerably less effort has been placed on understanding the relationship between mitigation and adaptation rather than focusing on them separately. However, currently the number of studies is increasing but still the literature 'does not yet discuss the role of policies and institutions *vis-à-vis* inter-relationships between adaptation and mitigation, nor does it discuss the implications of potential inter-relationships on policy and institutions' (Klein et al. 2007).

Adaptation options that are available to societies are likely to require inputs of energy, since by nature adaptation refers to activities that are undertaken either in addition to or instead of other activities (Klein et al. 2007). These activities can either be a large input in the construction of large-scale infrastructure or alternatively incremental use of energy in the provision of goods and services related to adaptation measures. Adaptation to the changes in the hydrological regimes and to ensure continuous availability of water is likely to demand continued inputs of energy. Adaptation can also have an impact on energy supply, particularly the availability of hydropower, if the availability of water for power production is reduced as a result of adaptation measures, particularly if the need for irrigation in agriculture increases. Changes in land use and land cover are the most pertinent area where inter-relationships between mitigation and adaptation take place. Deforestation has resulted in significant greenhouse gas emissions, largely through agriculture. Stopping and reversing this trend can potentially contribute not only to a reduction in greenhouse gas emissions but also contribute to the local climate and water resources and biodiversity.

4.2.4 New development opportunities through adaptation and mitigation

It is likely that new development opportunities emerge for the European regions in the wake of climate through adaptation and mitigation. As uncertainty is still relatively high in terms of the expected climate change impacts, it is difficult to estimate the kinds of development opportunities that can emerge across different sectors. Adaptation, as means of capitalising on climate change, is yet relatively rare in Europe, as the focus of adaptation policy has centred on risk management and the avoidance of damages as a result of the changing climate. Tourism and agriculture are sectors that are most likely to be impacted by climate change, and adaptation measures within these sectors need to focus on new development opportunities, whilst avoiding maladaptation.

Adaptation policy plays an important part in the realisation of opportunities that climate change can bring about. Currently, the main focus in adaptation policy in Europe has been on identification of vulnerabilities and management of risk in terms of expected impacts. A recent analysis of adaptation policy divides the objective of adaptation policy into four different aims: reduction of risk and sensitivity, increased coping capacity, capitalisation of changed climatic conditions and building of adaptive capacity (Massey, Bergsma 2008). In Western, Northern and Southern Europe policies that focus on capitalising on the changed climatic conditions have been given the lowest priority in national adaptation strategies. National strategies in Central Europe, however, place more emphasis on capitalisation, 22 percent of total policies, which is even more than increasing coping capacity. In addition, close to half of the measures in Northern Europe, and over half of measures in the three other regions are targeted towards reducing risk from expected changes.

4.2.5 Migration and Climate Change in Europe

Climate change is currently a key issue on the European policy agenda. Although the European Union strategy is based on solidarity for the affected member states and other countries outside of the EU, the link between climate change and migration has not been directly addressed yet. Much less has been done regarding the study of this topic at regional and local scales. The complex nature of the atmosphere and the lack of knowledge of all climate processes that affect the climate system make climate change predictions inherently uncertain. Furthermore, the speculative nature of many assumptions on migration trends makes the link of this subject with climate change difficult to unravel. Historical records and empirical studies suggest that migratory responses to climate variability cannot be explained through concepts such as hazard, risk or physical vulnerability alone. Migration implies a variety of factors, including both economic and social capital, to facilitate the process (Lutz, 2009; Kniveton et al 2008). Nonetheless, the long-distance and linear nature of this migration is not supported by robust scientific research, yet many authors agree that climate-related shocks and stresses will lead inevitably to massive migration movements.

Two questions arise while exploring the existing link between climate change and migration in Europe: (a) who are the potential climate change migrants, and (b) what climate change processes might cause population displacements to, within and where in the continent. In order to answer these questions, this brief report attempts to identify the possible impacts of climate change both in international as well as in internal migration within Europe. In this respect we must cite as a fundamental reference ESPON's DEMIFER project (Demographic and Migratory Flows Affecting European Regions and Cities) (DEMIFER 2010). This report highlights the difficulties and uncertainties related to data on migration processes linked to climate change, especially at the regional and local scales but nonetheless it provides certain valuable judgments on this issue for the future decades.

Most of the areas with the largest projected figures of population growth, such as South and Eastern Asia, happen to be also the most densely populated today. These areas, along with many other around the developing world, also likely to become vulnerable to climate change and associated effects over the next decades. Among other impacts this is likely to result in massive human displacements. Thus is predicted that 1 billion people, many of them from developing regions, will migrate due to climate change by 2050. Although slow-onset climate processes are expected to affect short or mid-distance migration flows, mainly within the countries or in neighbouring countries, the increasing frequency and intensity of some catastrophic extreme events related to climate change can also increase the risk of new patterns of migration, including long-distance flows, rather than the reinforcement of existing streams. However, empirical studies show that much of this migration is likely to occur within countries or in neighbouring countries and that people tend to return to their previous settlements after the disaster (Massey et al. 2010). Moreover, climate change displacements from developing countries are unlikely to reach very far because of poverty and because of the existence of mitigation measures through aid efforts. Nearby urban areas are more likely to experience massive arrivals. In sum "international migration is an expensive endeavour with significant resources required both to undertake the journey from other continents to Europe and especially to cross international borders" (Black et al 2008, 7).

Regarding European regions, changes in temperature, rainfall patterns and CO2 concentrations could affect agriculture, resulting in changes in yield productivity fostering internal but also international migration to European areas now sparsely populated such as those located in the North of the continent. On the other hand, the increasing occurrence of extreme weather events such as forest fires, heat waves, droughts or floods is likely to generate migration flows within and across countries, and sea-level rise could foster migration movements from low-lying urbanized areas of Atlantic Europe and the Mediterranean. Decreasing snow availability in certain mountain areas could hamper winter tourism and possibly lead to migration from these areas although perhaps not in appreciable terms given the already relatively small population (DEMIFER, 2010). The Mediterranean climate has proven to be the main factor attracting international migration of retirees from the United Kingdom, Germany or Scandinavia, especially towards Spain and Portugal. These migration flows could also be affected by climate change if the conditions of comfort in the Mediterranean decrease in summer, for instance. This may lead to an intensification of already existing seasonal flows by which especially the most well off European retirees return to their countries in the summer. However, the adaptability of Mediterranean countries could offset climate change impacts, for example with the use of air conditioning or recurring to desalination in case of water shortages. Likewise adaptation could take place by use of reliable technology.

In conclusion, the impact of climate change and related events on migratory flows to, from and within Europe is likely to be small. International migration may be affected by increasing costs and restrictive policies while internal movements within the continent do not appear to be very significant either - unless other adaptation measures fail. Nevertheless, we must add a note of caution to these statements since, as the authors of the DEMIFER report argue, lack of data and studies make reliable estimations nearly impossible.

5. Research implications

5.1 Comparison with other regional typologies

The new typology of regions developed by the ESPON Climate project provides a new perspective on existing regional typologies, many of which are used by EU policy-makers. Based on the findings presented in this report it is possible to already outline climate change based implications for these typologies. These implications point towards more in-depth, quantitative research that will systematically compare the average impact, adaptive capacity and vulnerability scores of the various types of regions.

As concerns Europe's *metropolitan regions*, it is clear that most exhibit high climate impact scores. This is not surprising giving the concentration of population, infrastructures and cultural assets in these regions. When looking at their vulnerability scores, many metropolitan regions have only low or even marginal vulnerability, because their adaptive capacity is generally higher than non-metropolitan regions. However, the metropoles along the (especially Southern-European) coasts, in the Alps and in South-East Europe still have a high vulnerability. Often this is due to a relatively low adaptive capacity (by European standards) in the relevant countries.

Examining the EU's typology of *urban and rural regions*, the same results as outlined above are true for the major urban centres. Urban regions along Europe's costs are clearly more vulnerable than most rural regions. Nevertheless, rural areas in Southern Europe also show moderate vulnerability values because of the hotter and drier future climate in these parts of Europe. In contrast, rural areas in central, northern-eastern and northern Europe have only a low, marginal or even positive vulnerability change due to only slightly worsening or even improving climatic conditions.

Europe's *mountain regions* are expected to be mostly adversely affected by climate change. This is particularly true for mountains in South-Eastern Europe, Greece, Spain and in the Alps. In the latter one can clearly see that the most severe impacts are to be expected on the southern side. Mountain regions in Scotland and Scandinavia also show medium to high vulnerability, but it is difficult to come to clear conclusions as regards the Norwegian regions because of the lack of data for many indicators there.

In Europe *sparsely populated regions* are primarily located in Scandinavia, Scotland and the interior of Spain. The Spanish regions - like most other Mediterranean regions - are negatively affected by a hotter and drier climate. On the contrary, the northern European regions are projected to suffer mostly from more precipitation and related problems like river flooding and flash floods, but their agricultural sector may benefit from the increase in temperature.

Islands can be found primarily in the Mediterranean and the northern Atlantic. On average islands are severely impacted by the projected climatic changes. For the Mediterranean islands (i. e. Mallorca) this is compounded by a relatively low adaptive capacity, leading to even higher vulnerability scores. However, one has to be cautious with conclusions regarding islands, because the CCLM model seems to have problems with climate projections for land cells with oceanic climate. Furthermore, CCLM unfortunately did not allow projections for Iceland.

Border regions are an important category of regions from a European policy point of view. Examining the impact and vulnerability scores of these regions it becomes apparent that there are very stark disparities between the regions of one cross-border corridor (i. e. between Austria and the neighbouring countries Czech Republic, Slovakia and Hungary). This is in part due to the often very different adaptive capacities of the respective countries, but also the sensitivities (e.g. in regard to population concentrations, settlement patterns, economic development) vary significantly across borders.

When analysing climate change implications for *regions in industrial transition*, it may be more important to consider mitigation instead of sensitivity and adaptive capacity. It can be expected that regions with industrial branches that are gaining in importance are likely to emit more greenhouse gases in the future. On the other hand, those regions with a declining restructuring manufacturing sector may in the future emit less greenhouse gases and thus make greater contributions to climate change mitigation.

Lastly, Europe's *outermost regions* are, by definition, not located in Europe. One can therefore expect that climate change will affect these regions completely differently. Since many of the outermost regions are coastal regions they will probably exhibit moderate or even high impacts, and possibly also have a relatively low adaptive capacity. Therefore these regions may have at least a moderate if not a high vulnerability (by European standards). However, it is not possible to undertake more than these general speculations because the climate change data that the project had access to did not include the outermost regions.

5.2 Issues for further analytical work and research, data gaps to overcome

It has to be stated that the ESPON Climate was the first attempt for a pan-European cross-sectoral climate change vulnerability assessment. A huge workload which was not properly considered by the project specification had to be spent on developing and fine-tuning the methodological framework. Moreover, the whole issue of climate change vulnerability is highly complex. Many studies had to be reviewed just about a single element of one of the many composite indicators that the ESPON Climate project developed. Considering the given restrictions in time and budget, ESPON Climate was not able to fulfil all of the demanding expectations which are documented i.e. in the response to the interim report (e.g. identifying the impact separately for the multitude of types of species). However, simply the size of the data base, which clearly exceeds all previous ESPON projects, underlines the complexity of the issue and should be seen as proof for the enormous workload which was dedicated to this analysis. Moreover, ESPON climate developed several advanced methods for assessing climate change impacts for the pan-European study on a very fine-grained scale. The assessment of many indicators was performed on a 100 x 100 metre grid cell basis, e.g. to identify exactly those parts of a region's population which are sensitive to river flooding inundation.

5.3 Recommendations for pan-European monitoring

Finally, hardly any data are available for dynamic sensitivity indicators although a sophisticated vulnerability assessment should be based on projections for both exposure and sensitivity referring to the same past and future time periods. The ESPON Climate project is well aware of this need for further analytical research, which is, however, clearly beyond the scope of a single applied research project. It was possible to underline the relevance of dynamic sensitivity data by using the population projection for 2100 which came from the ESPON DEMIFER project. However, for other relevant data (e.g. settlement changes, economic development and the environment in the year 2100) no data exist at all or only for parts of the ESPON space.

For the sake of a (continuous) pan-European monitoring such data need to be consolidated by central institutions and be provided corresponding to a common analytical framework which may lean on the one developed within this project. A positive indication in this respect is the new clearinghouse initiated by DG Climate Action. Such an institution may be a good starting point for a common shared and harmonized database. Furthermore, adequate tools of data provision and for analysis considering the special demands in the context of climate change may be provided. For a more decentralized pan-European monitoring harmonized methodologies are indispensable. Ultimately all advancements will still face the issues already discussed within this report - uncertainty about future climate change but also about future regional development. Here, a regular monitoring may also hold potential as to provide better projections on dynamic indicators of regional sensitivity and adaptive capacity.

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The ESPON 2013 Programme is part-financed by the European Regional Development Fund, the EU Member States and the Partner States Iceland, Liechtenstein, Norway and Switzerland. It shall support policy development in relation to the aim of territorial cohesion and a harmonious development of the European territory.

ISBN