



Territorial Observation No. 7
May 2013

Territorial Dynamics in Europe
Natural Hazards and Climate Change
in European Regions

The ESPON 2013 Programme

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The content of this publication is based on results provided by projects under the ESPON 2013 Programme. As such, the maps and their corresponding texts do not necessarily reflect the opinion of the ESPON Monitoring Committee.

Europe is currently affected by two major global challenges. One is the economic and financial crisis. The other is the gradual change of climatic conditions.

The Europe 2020 Strategy is responding to these challenges. EU Cohesion policy 2014-2020 will provide investment support for smart, sustainable and inclusive growth. This will be guided by eleven thematic objectives, including also the promotion of climate change adaptation and risk prevention and management.

Like the impacts of the economic and financial crises, the impacts of climate change affect and will affect the European territory. However not all regions and cities are and will be affected in the same way. In some places these challenges have little impacts. In other places, they will in the worst case reinforce each other and provide a serious challenge for future growth and employment.

This diversity of impacts within Europe is very important to understand in order to shape the best possible actions at national, regional and local levels. Evidence informed responses are necessary which are based on solid and comparable research, analysis

and data that cover the entire European territory, its regions and cities.

The ESPON 2013 Programme has been set up to deliver on this particular task.

Observing impacts of natural hazards and climate change is of relevance on two accounts. On the one hand, there is a need to become aware of challenges that might affect development negatively and even pose risk for the economy as well as for people. On the other hand, there are future development opportunities and dynamics, that could become new potentials for growth.

Against this backdrop this report aims at identifying some territorially differentiated policy options linked to urban and regional development in order to tackle climate change and natural hazard related risks.

This ESPON Territorial Observation no. 7 on “Natural Hazards and Climate Change in European Regions” uses results from different ESPON projects. Most of the information, maps and data are based on a recent ESPON map-update on natural hazards¹ and the Applied Research project “ESPON CLIMATE - Climate

Change and Territorial Effects on Regions and Local Economies in Europe”.

European territorial evidence on the diversity of effects of the current economic and financial crisis affecting the world economy, its regions and cities, is not reflected in depth in this publication.

The ESPON Programme has at the moment the Applied Research project “ECR2 - Economic Crisis: Resilience of Regions” in progress that will provide new insight on the territorial dimension of the current crisis. This project will deliver its results and final findings by April 2014.

All underlying reports and information are available at www.espon.eu

¹ “Update of Maps and Related Data on Natural Hazards” by GeoVille Environmental Services.

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Abbreviations

CCLM:	COSMO model in CLimate Mode
CLC:	CORINE Land Cover
CSF:	Common Strategic Framework
EEA:	European Environmental Agency
GDP:	Gross Domestic Product
IPCC:	Intergovernmental Panel on Climate Change
UNISDR:	United Nations International Strategy for Disaster Reduction

Territorial dynamics in Europe

Natural hazards and climate change in European regions

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1 – Executive summary

For many parts of Europe, there are growing concerns with the impacts of natural hazards. This is related to the loss of life as well as their major costs, both financial and non financial. The degree of natural hazard risks associated with climate change, for example flood, forest fires and heat waves is actually not fully understood. However, these events occur with apparent increasing frequency and magnitude.

As a response, recent political priorities include (a) provision of the fullest protection to European citizens and their property, (b) maintenance of the vital social and economic capital invested in cities and transportation systems, as well as (c) maintenance of environmental assets under threat.

Climate change itself is widely acknowledged as one of the major challenges for our society and a key policy issue. It clearly poses short-term challenges and also increasingly severe long-term threats. At international, European, national, regional and local levels, climate change adaptation and mitigation measures increasingly form a standard part of policy formulations for territorial development. At European level, the European Commission and EU Member States are addressing the issue from different perspectives.

Natural hazards and impacts of climate change affect and will affect European regions and cities in an asymmetric way, with differences in magnitude and timescale. These incidents and consequences hamper contributions to overall objectives of the Europe 2020 Strategy of smart, sustainable and inclusive growth. EU Cohesion policy supports adaptation and mitigation

measures as eligible expenditure and many projects around Europe are taking steps towards the prevention of potential impacts. Future European Structural Investment Funds 2014-2020 are envisaged to and continue providing European funding to projects with this focus. The Common Strategic Framework (CSF) is expected to include an objective promoting climate change adaptation and risk prevention and management.

In April 2013 the European Commission adopted “An EU Strategy on Adaptation to Climate Change”, identifying that this theme is currently on the top of the policy agenda. This strategy is promoting greater coordination between Member States. It is supporting the development of a coherent approach aiming at addressing adaptation strategies in relevant EU sector policies. Furthermore it outlines that adaptation action should be implemented in full coordination with the disaster risk management policies that the EU and the Member States are developing.

At European level policy makers agreed in 2010 on specific targets for the Europe 2020 Strategy, including reduction in greenhouse gas emission by at least 20% compared to 1990 or by 30% if the conditions are right; an increased share of energy supplied from renewable sources (20%), and a 20% rise in energy efficiency.

One of the flagship initiatives supporting the implementation of the Europe 2020 Strategy is the initiative “Resource efficient Europe”. This initiative seeks “a vision of structural and technological

changes...which will allow the EU to achieve its emissions reduction and biodiversity targets”. It includes disaster prevention and response to address climate change, using the contribution of cohesion, agricultural, rural development, and maritime policies. A specific focus is put on adaptation measures based on more efficient use of resources.

The Territorial Agenda of the European Union 2020 notes that the impacts of climate change and its attendant risks vary considerably across Europe with differential impacts and different degrees of vulnerability. It addresses these geographically diverse impacts by specifying regional risk profiles, and emphasising the opportunities that exist in relation to both adaptation and mitigation challenges. Furthermore the Territorial Agenda notes that these challenges necessitate the territorial coordination of policies especially those related to climate, energy, water management, agriculture, housing, tourism and transport.

Hence, integrated and coordinated territorial approaches are of particular relevance to the management of natural hazards and climate change related risks, particularly when these cross administrative boundaries. The same is the case for finding opportunities for new development, growth and job creation that may become a result of slowly changing climatic conditions.

1.1 How to understand vulnerability

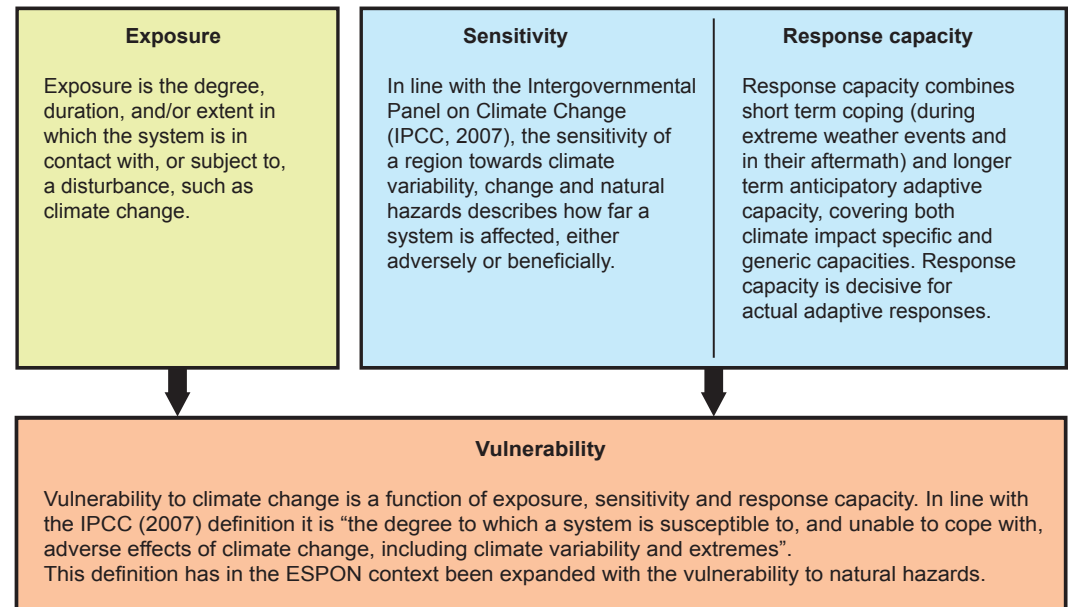
The territorial evidence developed by ESPON on natural hazards and climate change shows the territorial distribution of exposure, sensitivity and response capacity as well as vulnerability associated with these challenges.

The vulnerability of a region is determined by the combination of its:

- Degree of exposure – the extent to which a region is facing natural hazard or climate change impacts;
- Sensitivity – the economic, social and ecological damage potential which is assessed in this context, by using the regional GDP per capita (financial damage potential), population density (number of people affected) and naturalness (degree of environmental assets affected); and
- Capacities to respond – the ability to react to and mitigate which is in this context addressed by taking into account national GDP per capita.

In dealing with natural hazards and climate change the following terms and definitions have been used (Figure 1):

Figure 1 Overview of the definitions related to vulnerability



1.2 Points for policy consideration

There are eight points for consideration by policy makers:

Regions in South and South East Europe most exposed. The majority of the regions with “high” to “very high” natural hazard exposure are situated in the South and South East of Europe. That is, large parts of the Iberian Peninsula, the South of France, Italy, Greece, Bulgaria and Romania. High aggregated hazard risks in these territories are caused by combinations of several hazards such as droughts, extreme temperatures, forest fires or floods.

Cities and core of Europe with high sensitivity. The magnitude of social and economic assets in cities makes them highly sensitive to natural hazards impacts and future climate change due to the high damage potential. This analysis is also valid for several regions from the UK to Benelux, Germany and Northern Italy which are characterised by a high level of industry and services with related high population densities.

High response capacity in the North and West of Europe. Nordic and Western European countries are less vulnerable to natural hazards and climate change due to their high level of national GDP per capita, determining their response capacity.

Vulnerability determined by local conditions. Local characteristics, as for example the exposure of a region to natural hazards and the population density, are decisive for the vulnerability of a region. Consequently local decision making is central to the delivery of territorially defined place-based policies addressing natural hazards and climate change. Regional and territorial differences in exposure, sensitivity and vulnerability, require better connection and integration of risk reduction, adaptation and mitigation measures.

Vulnerability might rise in future. Potential exposure to natural hazard risks and climate change impacts differs substantially between European regions. Furthermore imbalances in vulnerability to these risks will almost certainly increase in the future, as the economic resilience of some cities and regions, influenced among others by the national GDP per capita, is reduced by impacts of the economic crisis. Therefore the capacity to respond to natural hazards and climate change is undermined.

New opportunities arising. Besides the challenges that need to be faced with regard to climate change, new opportunities also arise for cities and regions. This includes new business opportunities, the opening of new shipping routes in the Arctic, and increased crop variety and yields.

A pro-active approach towards the consequences of climate change which also looks to explore new opportunities is essential in order to support the territorial development of the European Union towards Europe 2020 strategic objectives.

Better understanding of the territorial dimension needed. It is crucial to understand both the diversity and accumulation of the impacts of natural hazards and climate change. Accordingly territorially differentiated adaptation strategies at the European, national and regional levels would need to be developed.

Integration of all levels of governance is key. The implementation of integrated and territorial approaches that simultaneously ensure compatibility between sectors and regions, as well as between all levels of policy making, is a major challenge. Furthermore, the development of interconnections between the management of natural hazard risks and climate change adaptation and mitigation measures will form essential foundations for future policy formulations.

2 – Exposure of European regions

The “20/20/20” climate/energy targets defined by the European Commission in the Europe 2020 Strategy aim at the reduction of greenhouse gas emissions, an increased share of energy supplied from renewable sources and rising energy efficiency.

The magnitude of threats attributable to natural hazards and climate change and their territorial distribution is at present not fully known. One key knowledge gap that has been identified in the EU Strategy on Adaptation to Climate Change is regional and local-level analyses and risk assessments. This Territorial Observation shows that specific types of regions are at particular risk for example coastal areas for sea-level rise or river basins for flooding, considering also the increasing incidence of both storms and extreme temperatures. Although affecting a larger area, these events still retain regional characteristics.

Drivers of climate change include natural processes such as volcanic eruptions, and solar variations, or human activities, including for example actions leading to substantial greenhouse gas emissions.

Definition of climate change

According to the IPCC (2007) climate change “refers to any change in climate over time, whether due to natural variability or as a result of human activity”.

The climate of a region and consequently its changes are defined by diverse climatic variables such as the annual mean temperature, frost or summer days, days with heavy rainfall or the annual precipitation. As several natural hazards are driven by climatic variables, climatic changes also influence the exposure to natural hazards.

Definition of natural hazard

The United Nations International Strategy for Disaster Reduction (UNISDR, 2009) defines a natural hazard as a “natural process or phenomenon that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage”.

Natural hazards may be categorised according to the European Environment Agency (EEA, 2010) definitions into two fundamental categories: hydro-meteorological and geophysical.

The exposure to two climatic variables (i.e. change in annual mean temperature and relative change in annual mean precipitation in summer months), two hydro-meteorological hazards (i.e. floods and droughts) and one geophysical hazard (i.e. landslides) is discussed in the following section. Subsequently, the aggregated hazard exposure potential for the European territory is presented, taking into consideration eleven natural hazards.

2.1 Exposure to climate change

For different parts of the European territory, diverse impacts of climate change can be identified.

Main challenges in Europe differ geographically. The Arctic faces major changes including a higher than average temperature increase. As a consequence the reduction of ice cover is accelerating and projected to continue to impact the local natural and human systems. In Northern Europe more frequent and intense extreme weather events in the medium to long term are anticipated causing, for example, more variable crop yields. Coastal flooding has affected low-lying coastal areas in North-Western Europe in the past, and the risks of experiencing more severe impacts are expected to increase here due to sea-level rise, and the increased risk of storm surges. Temperature extremes are expected in Central and Eastern Europe. In the Mediterranean regions, an increase in temperature accompanied by a decrease in precipitation is projected.

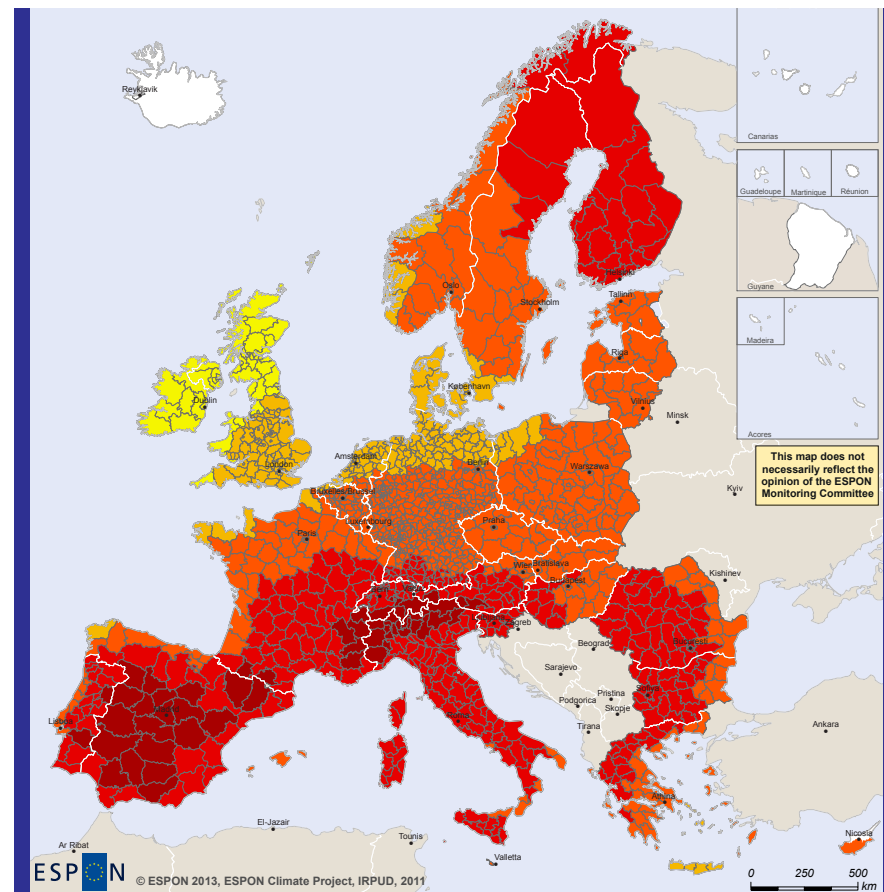
Climatic conditions lead to territorial differences. Territorial differences arise as a result of diverse climate-related stimuli, for example change in annual mean temperature, or the relative change in annual mean precipitation. However, the same change in summer temperature may affect the tourist sector both positively or negatively. Similarly, the agricultural sector may benefit or not from increased precipitation. The effects depend on the existing climatic conditions and a variety of other factors.

2 – Exposure of European regions

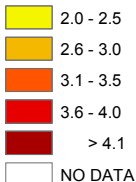
Mean temperatures projected to rise. Annual mean temperature, an important indicator of climate change, indicates regional variations of change in temperature. The annual mean temperatures are expected to increase between 2.0 and 4.1°C in the EU 27 Member States, Liechtenstein, Norway and Switzerland over the period 2071-2100 compared to the reference period 1961-1990 (Map 1).

The UK, Ireland, Denmark and parts of the Netherlands exhibit the smallest temperature change of up to 3.0°C. Western and Northern parts of France, Belgium, most parts of Germany, Poland, the Czech Republic, Slovakia and parts of Sweden, Norway as well as the Baltic states, increases between 3.0 and 3.5°C; while Southern and South-Eastern Europe as well as Northern Scandinavia and Finland will experience the highest temperature changes with absolute changes of more than 3.5°C. In the inland of Spain, parts of Portugal and the Alpine region, temperature rises of more than 4.0°C will occur.

Map 1 Change in annual mean temperature



ESPON
 © ESPON 2013, ESPON Climate Project, IRPUD, 2011



Regional level: NUTS 3
 Source: ESPON 2013 Database
 Origin of data: IRPUD, own calculations based on Lautenschlager et al. 2009
 © EuroGeographics Association for administrative boundaries

Change in annual mean air temperature in 2 metres above surface.
 Climatic changes derived from a comparison of 1961-1990 and 2071-2100 climate projections by the COSMO model in Climate Mode (CCLM) for the IPCC SRES A1B scenario.

2 – Exposure of European regions

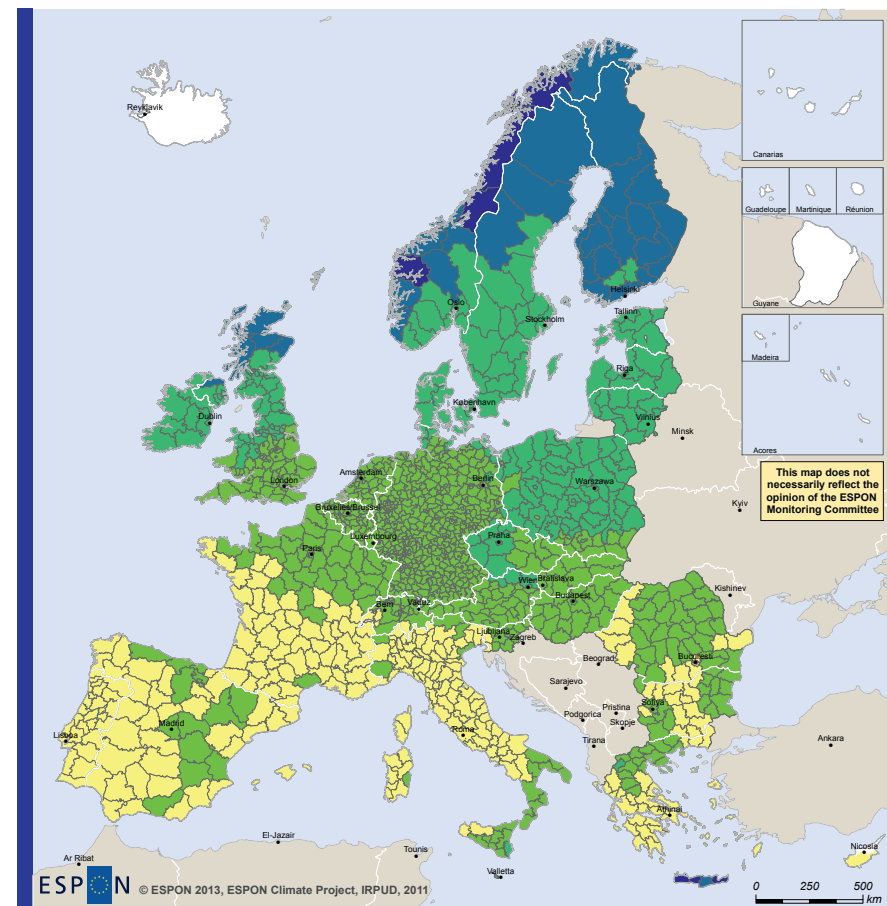
It is also projected that some regions will experience a decrease in summer precipitation in future, ranging up to 40% and more (Map 2). This reduction increases drought risks in these regions predominantly located in Spain, Italy, Cyprus, as well as parts of France, Greece, Bulgaria and Romania. In contrast parts of Scandinavia and Finland as well as Northern UK are projected to experience precipitation increases of over 20%.

Example: Changes in temperature in the Mediterranean

Climate is a fundamental element, and perhaps the key influencing factor in explaining the attractiveness of the Spanish Mediterranean Coast for domestic and international tourists. Here climatic conditions will change considerably. The annual mean temperature in the Mediterranean basin will increase more than 3.5 °C, while the relative change in annual mean precipitation in summer month may decrease considerably ($\leq -40\%$), thus limiting the amount of water available for human and non-human uses.

One extreme case is the Costa del Sol tourist area in Spain, where the increase in mean temperature is projected to be between 3.6 °C and 4.0 °C, and the relative decrease in annual mean precipitation in summer months up to 40%.

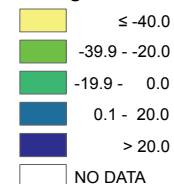
Map 2 Relative change in annual mean precipitation in summer



ESPON © ESPON 2013, ESPON Climate Project, IRPUD, 2011

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Change in annual mean precipitation in summer months (in %)



Regional Level: NUTS 3
 Source: ESPON 2013 Database
 Origin of data: IRPUD
 Own calculations based on Lautenschlager et al. 2009
 © EuroGeographics Association for administrative boundaries

Relative change in annual mean precipitation in meteorological summer months (June - August).
 Change in annual mean air temperature in 2 metres above surface.
 Climatic changes derived from a comparison of 1961-1990 and 2071-2100 climate projections by the COSMO model in Climate Mode (CCLM) for the IPCC SRES A1B scenario.

2.2 Exposure to hydro-meteorological hazards

The majority of natural hazards driven by climate change belong to the hydro-meteorological grouping including for example floods and drought. Risk, frequency and intensity of these hazards in an area are influenced by changes in climatic variables.

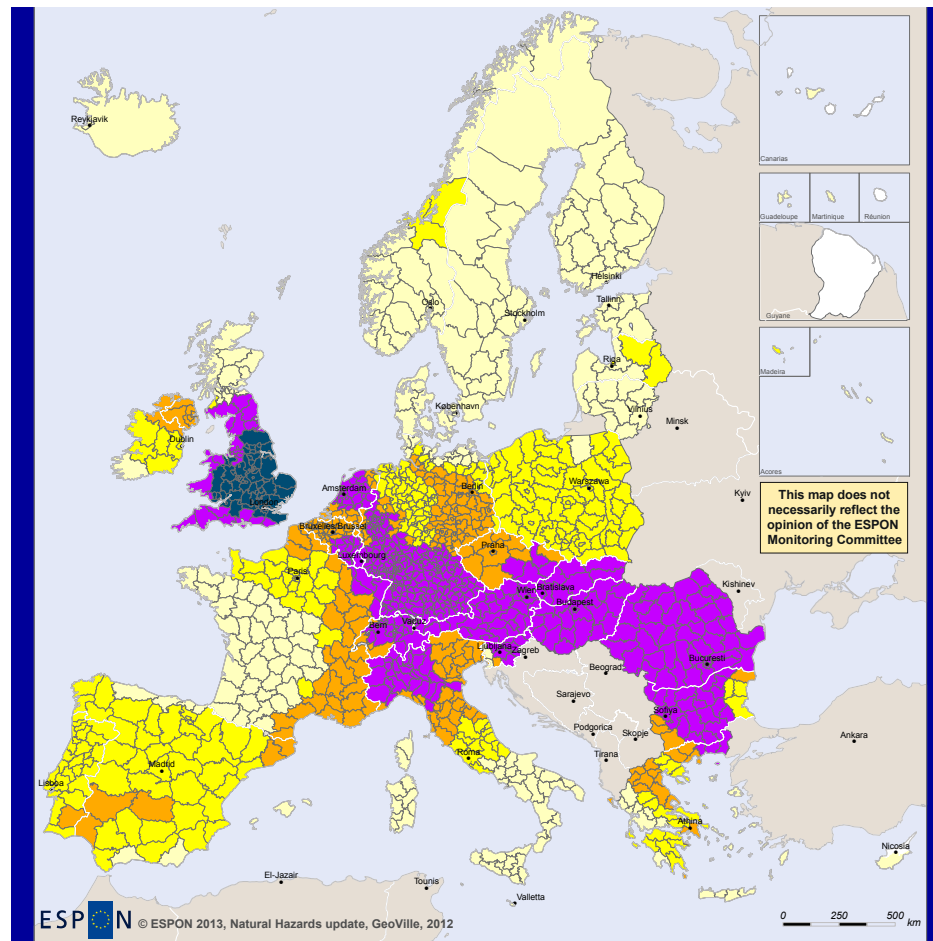
Hydro-meteorological hazards have high effects.

Natural hazard events may be coupled, such as for example a storm carrying huge volumes of precipitation that leads to flash floods. Overall, hydro-meteorological hazards are considered a greater threat than geophysical hazards such as earthquakes or landslides, given the extensive areas affected. The EEA (2012) identifies river flooding together with wind related storms as the most important natural hazards in the EU in terms of economic loss.

The spatial distribution of high and very high flood hazard risk did not change significantly from 2002 to 2012. However, flood occurrence is projected to increase even further with climate change. The main reason for high flood occurrence is the general increase in winter precipitation, apparent in almost all regions of Europe except in the Mediterranean.

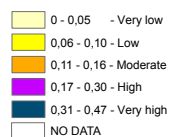
Flooding risks along the Rhine and Danube. The highest average values for floods per year measured for each river basin in Europe are found in the low-lying areas along the Rhine and the Danube rivers (Map 3). The other river basins with high flood risks are the Po river in Northern Italy and all river systems in England.

Map 3 Flood hazard



ESPON © ESPON 2013, Natural Hazards update, GeoVille, 2012

Average count of floods per year and river basin (1985-2012)



Regional Level: NUTS 3
 Source: ESPON 2013 Database
 Origin of data: GeoVille Environmental Services
 © Flood events - Dartmouth Flood Observatory archives 2012
 © River basin - EEA 2012
 © EuroGeographics Association for administrative boundaries

2 – Exposure of European regions

Example: Tisza river

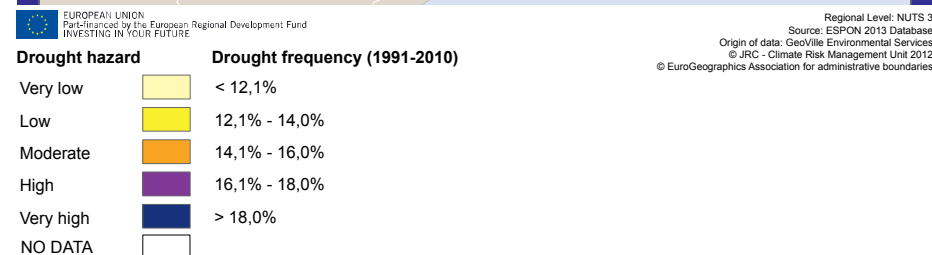
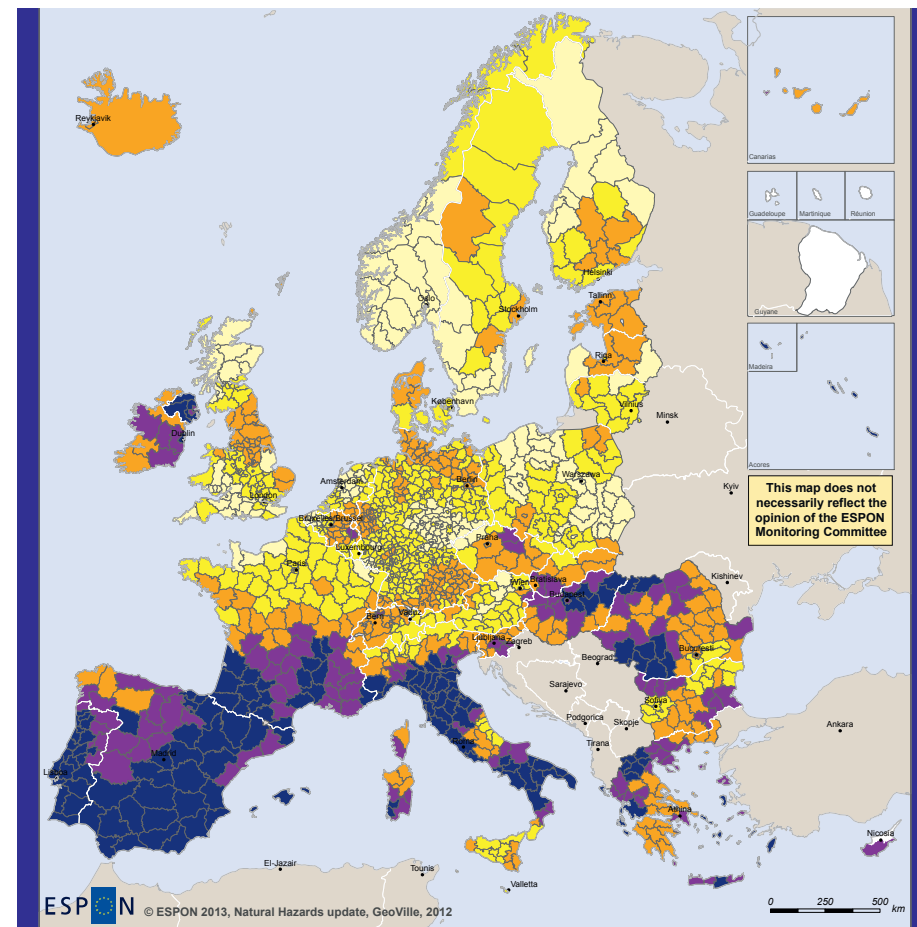
The river Tisza, flowing roughly along the Romanian border and through Hungary, is one of the tributaries of the river Danube and a good illustration of the territorial nature of natural hazards. The river basin covers nearly 160 000 km² and has about 14 million inhabitants. Extreme weather phenomena are already a serious problem in the region and the frequency of extreme weather events in the context of droughts and floods are expected to increase as a result of climate change.

An impact analysis showed that most negative physical impacts are to be expected on the upstream, mountainous and hilly regions of the Tisza and its tributaries, although most of the current potential flood prone areas are on the plain in the downstream river sections. In terms of economic impact the picture is more diverse, with the greatest impacts predicted for the lowlands of the Tisza basin.

Drought Risks in the Mediterranean. The European territory faced droughts during the last decades (Map 4). Regions with a moderate to high drought risk are predominantly located in the Mediterranean region. However, parts of the Baltic States Region also show a drought frequency above normal values, due to the major drought of 2005 and 2006.

Nonetheless, the Carpathian Region, including large parts of Hungary and Romania, are among the regions with greatest drought risk over the past 20 years, and even some Irish regions despite normally substantial rainfall, have between 2003-2005 experienced annual precipitation significantly below the long-term mean.

Map 4 Drought frequency based drought hazard



2 – Exposure of European regions

2.3 Exposure to geophysical hazards

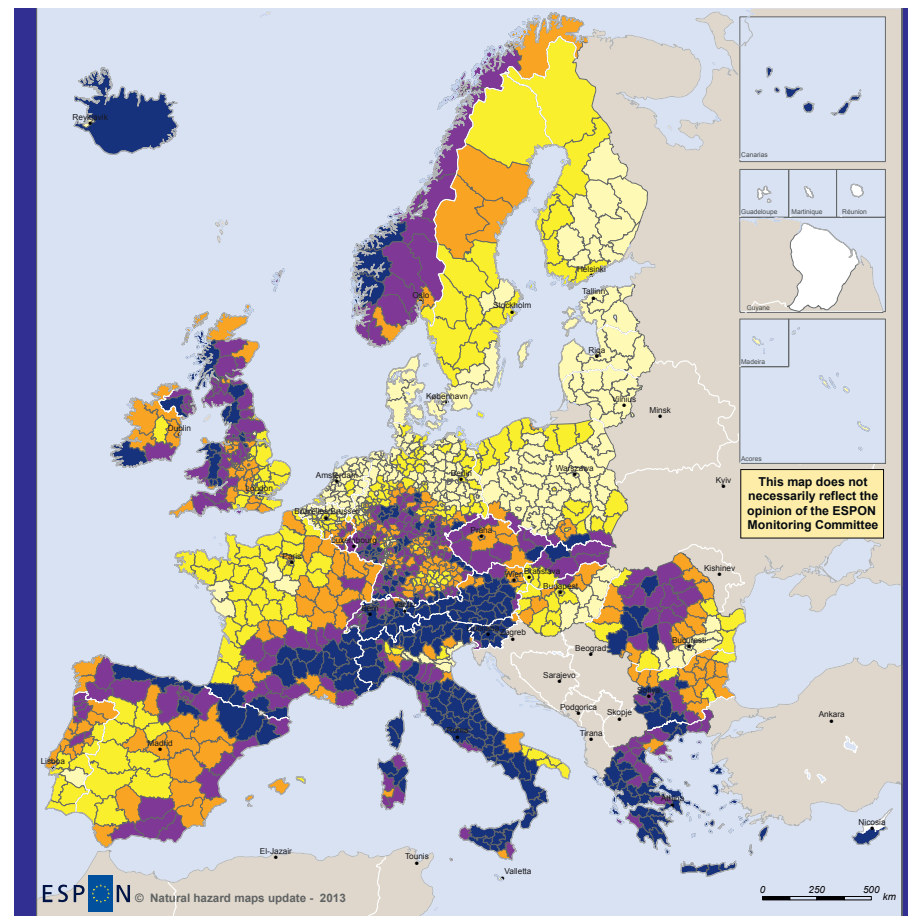
Avalanches, earthquakes, landslides and volcanic eruptions belong to the group of geophysical hazards. They possess destructive power and are substantially unpredictable, for example the recent earthquakes and eruptions of Mount Etna in Italy. Nonetheless, these hazards are geographically highly prescribed and rather concentrated.

Landslides as well as avalanches are driven by climate change but are geophysical hazards due to their well defined geographical specifics. In contrast to floods, landslides do not cause significant damage even if landslide occurrence is widespread across Europe (Map 5).

The highest exposures to landslides, though, can also be identified in South and South-East of Europe, adding up to the previously identified high incidence of hazards attributable to climate variables and other natural hazards in these regions.

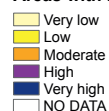
The following section presents the aggregated hazard risk for European regions.

Map 5 Landslide hazard



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Areas with landslide hazard (2012)



Regional level: NUTS 3 2010
Source: ESPON 2013 DATABASE
Author: GeoVille Environmental Services, 2013
Origin of data:
© JRC and BGR - European Landslide Susceptibility Map (ELSM1000 v1) - Günther et al., 2013
Cyprus: ESPON landslide hazard map 2006, Iceland: Icelandic Met Office
© EuroGeographics Association for administrative boundaries, 2010

This NUTS 3 aggregation was based on the 1 km resolution
European Landslide Susceptibility Map (ELSM1000) version 1 (Günther et al., 2013)*

*Günther, A., Reichenbach, P., Malet, J.-P., Van Den Eeckhaut, M., Hervás, J., Dashwood, C., Guzzetti, F. 2013.
Tier-based approaches for landslide susceptibility assessment in Europe. Landslides, doi: 10.1007/s10346-012-0349-1.

2 – Exposure of European regions

2.4 Combined exposure to natural hazards

Some regions are affected by or at risk of several types of hazards, whereas other regions are hardly at risk at all (Map 6). Regions with high risk potential are especially in need of adaptation and mitigation measures. Nevertheless, to be able to determine which types or combinations of measures could be helpful, one has to go back to the single hazards.

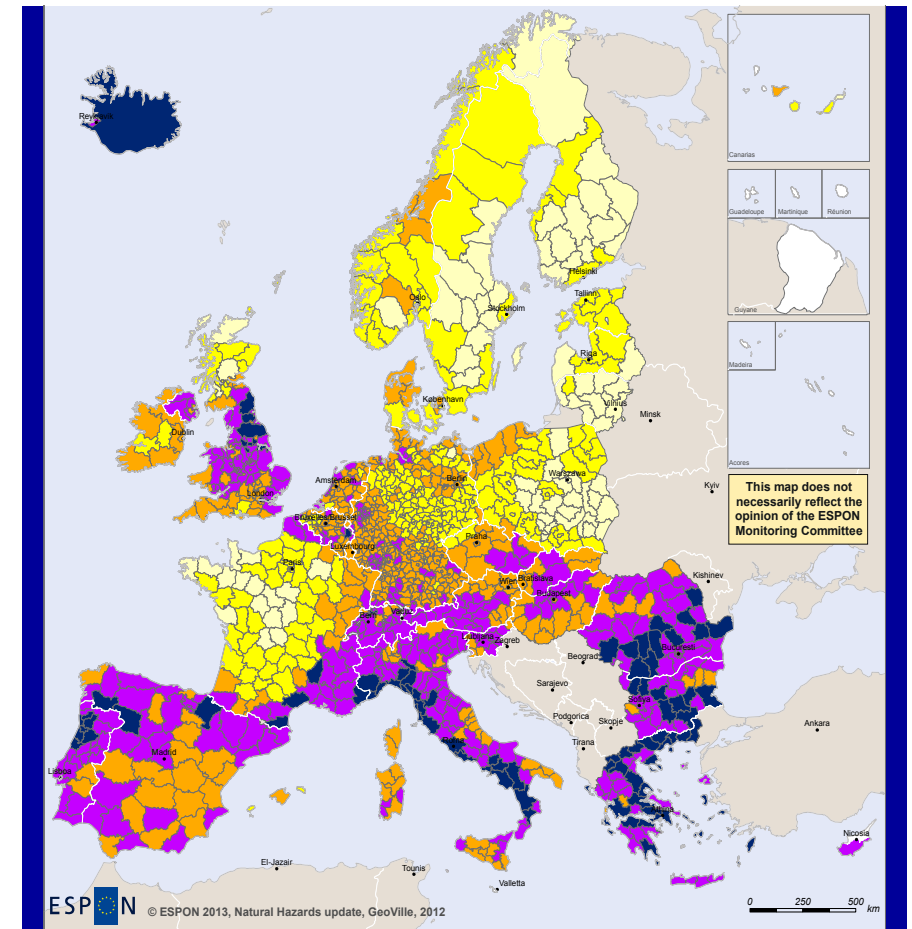
Regions in South and South East Europe most exposed. All Southern European regions have a high aggregated hazard risk and are especially affected by droughts, extreme temperatures and forest fires. In addition, the Northern Iberian Peninsula shows great exposure to winter storms. Italy and Greece are potentially affected by volcanic eruptions and tsunamis, whilst Eastern European regions have additional high potential for floods.

In Northern Europe, it is mainly Great Britain and Iceland that are characterised by high and very high risk values. Iceland stands out in many respects, in particular in relation to its hazard potential concerning avalanches, earthquakes, volcanic eruptions, winter storms and storm surges as well as tsunamis. The British Isles, and in particular the Eastern part of North and Central England, are potentially impacted by floods, storm surges and winter storms, landslides, as well as droughts.

Construction of Map 6

To identify those regions under threat by more than one natural hazard, an aggregated hazard exposure potential can be used. This potential is based on a weighted aggregate of single natural hazard exposures.

Map 6 Aggregated hazard exposure potential



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 Regional Level: NUTS 3
 Source: ESPON 2013 Database
 Origin of data: GeoVille Environmental Services, 2012
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Natural hazard exposure potential



The aggregated hazard exposure potential was calculated as weighted combination of 11 natural hazards:

- 1) Average floods per year/catchment, 1985 – 2011 (weight 19)
- 2) Observed forest fires, biogeographic regions, 1997 – 2012 (weight 14)
- 3) Drought frequency, 1991 – 2010 (weight 13)
- 4) Modelled earthquake hazard, 2010 (weight 12)
- 5) Occurrence of winter and tropical storms, 2006 (weight 10)
- 6) Extreme temperatures (Occurrence of warm and cold spells), 1981 – 2010 (weight 9)
- 7) Landslide occurrence, 2012 (weight 8)
- 8) Storm surge occurrence, 2012 (weight 7)
- 9) Potential avalanche occurrence, 2000-2011 (weight 3)
- 10) Occurrence of volcanic eruptions, 10,000 B.C. – 2012 (weight 3)
- 11) Tsunami occurrence, 2000 B.C. – 2012 (weight 2)

3 – Sensitivity and response capacity of European regions

The question is not only which regions are most exposed to natural hazards, but also which regions are most sensitive to climate change and natural disasters, due to high damage potential of economic, social and natural assets.

The sensitivity of European cities and regions is assessed in the following sections. Subsequently, the response capacity and finally the combined sensitivity and response capacity of European regions is discussed.

3.1 Sensitivity of European regions

Reinforcing impacts of socio-economic and climate change drivers. Existing socio-economic differences may be increased by the impacts of natural hazards and climate change. For natural hazard risks associated with climate change, a progressive dynamic can be identified. Risks related to climate change and socio-economic transformation, though, can provide a potentially volatile and even unpredictable dynamic. These developments may increase or reduce the impacts of climate change.

Natural hazards and climate change present risks to production, distribution as well as consumption and hence to the economy of a region. The social dimension of sensitivity acknowledges the sensitivity of people. Especially poor and more vulnerable population groups, for example the oldest and the youngest, are considered sensitive. Furthermore, the environmental fragility needs to be considered in this context.

Severe demographic changes also affect a region and its population. Furthermore, in response to economic transformations, economic migration has influenced the territorial distribution of populations, and thereby had impact on regions' sensitivity to natural hazards and climate change. Several Eastern European countries, for example, are suffering from both out-migration as well as ageing populations, trends which will probably continue in the future. The latter is of relevance as an older population is more sensitive to heat and less able to adapt to climate change.

Example: Sensitivity of a delta region in the Netherlands

Due to both sea level rise and an increase in extreme water discharge from the main rivers, the increase in flood hazard and drought are recognized as the biggest challenges for the Netherlands in relation to climate change. In total 56% of the Netherlands, where almost 70% of the population is concentrated, is prone to flooding (Map 3).

3.2 Response capacity of European regions

The sensitivity of a region has to be observed in order to take advantage of opportunities to moderate potential damages of European regions or to respond adequately to the consequences of natural hazards and climate change. Equally relevant, however, is the region's ability to cope with or adapt to these challenges, i.e. its response capacity. These capacities are decisive in minimising natural hazard and climate change risks.

The response capacity of a region is considered a significant element of future territorial disparities and hence relevant to discussions on the implications for territorial cohesion.

Challenges for regions with low response capacity.

There are significant differences in the economic, technical, and institutional capacity to cope with and adapt to natural hazards and climate change across Europe. When natural hazards or impacts of climate change affect regions with a low response capacity, the consequences for these region can be severe.

Competitiveness of most challenged regions in danger.

Peripheral regions in the East and South have a lower level of response capacity than the North of Europe when taking into account the national GDP per capita. This may reduce the competitiveness of these regions which already suffer from low economic competitive performance. However, the IPCC (2007) indicated that Europe will be less affected by climate change as compared with other major economic regions in the world, such as China, South East Asia and the emerging economies such as Brazil and India.

The economic crisis is affecting the response capacity of a region.

The economic and financial crisis intensifies economic and social pressure for a number of territories throughout Europe, especially Southern European countries like Greece, Spain, Italy and Portugal as it further reduces individual as well as collective response capacities.

3.3 Combined sensitivity and response capacity

Changes in the demographic profile or economic performance of a region are processes that are influencing the regional sensitivity and response capacity to climate change and natural hazard related impacts. Integrating the sensitivity of a region with its capacity to cope with or adapt to, permits the identification of regions where action seems necessary.

The sensitivity of European regions regarding their economic, social and natural assets together with their potential response capacity, can be assessed (Figure 2, Map 7). It is important to note that sensitivity and response capacity are opposing components with high sensitivity being negative and high response capacity being positive for the future development of a region.

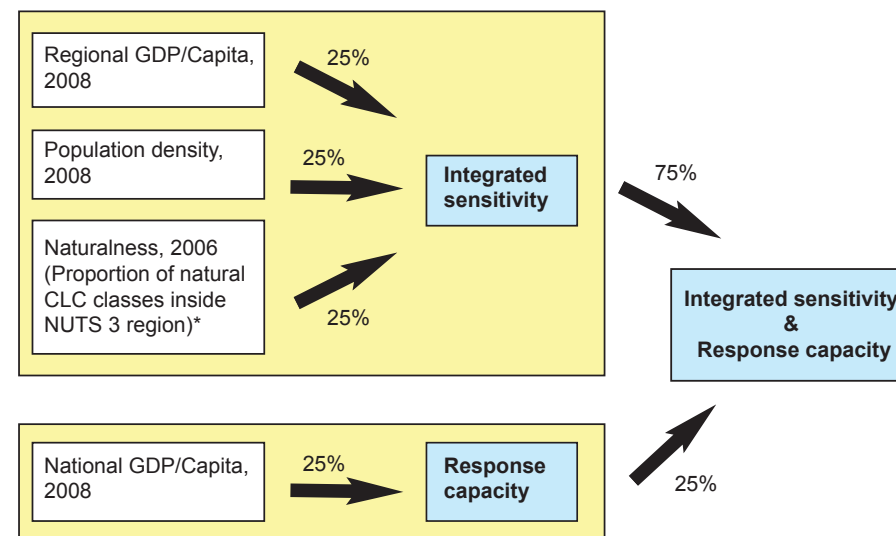
Example: Response actions in Malmö (Sweden)

The sustainable urban drainage systems in Malmö (Sweden) are an example of the improvement of the socio-economic and environmental situation arising from responses to natural hazards.

The neighbourhood of Augustenborg has experienced periods of socio-economic decline in recent decades, and at the same time frequently suffered from floods caused by overflowing drainage systems. The town benefitted from significant regeneration between 1998 and 2002, in response to difficult socio-economic challenges in the neighbourhood. Projects were implemented addressing flood risk management, waste management and biodiversity improvements.

Significant infrastructure transformations took place as a result, focusing on the creation of sustainable urban drainage systems, including ditches, retention ponds, green roofs and green spaces. The projects were undertaken collaboratively by city council and social housing representatives, with extensive residents' participation. The project succeeded as rainwater runoff rates decreased by half and green space increased, improving the area's image and the socio-economic situation.

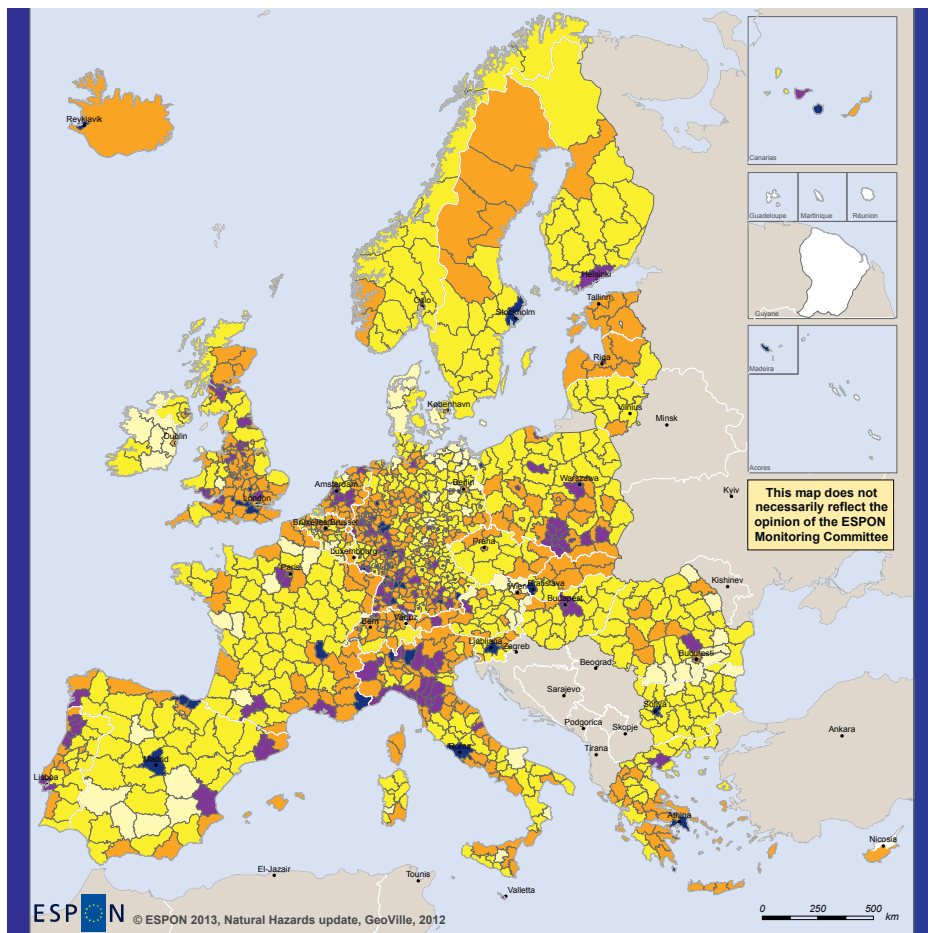
Figure 2 Workflow of indicator elaboration for integrated sensitivity and response capacity



* For Greece, CLC 2000 data was used.

3 – Sensitivity and response capacity of European regions

Map 7 Sensitivity and response capacity of European regions



Integrated sensitivity & response capacity (2008)

- Very low challenge
- Low challenge
- Moderate challenge
- High challenge
- Very high challenge
- NO DATA

Regional level: NUTS 3
 Source: ESPON 2013 Database
 Origin of data: GeoVille Environmental Services 2012
 Eurostat, EEA - CLC 2006*
 © EuroGeographics Association for administrative boundaries
 * Greece: EEA - CLC 2000

High sensitivity of cities. Predominantly urban regions have a great sensitivity in relation to natural hazards and climate change (Map 7, Figure 3). Cities are facing the highest challenges as they are home to a major part of the population and are crucial to Europe’s economy as centres of major economic assets and innovative activities, possessing a high damage potential.

Also the complexity of city systems providing and managing energy, water, waste, food and other services needs to be considered when dealing with natural hazard impacts, current climate variability and future climate change.

The growth of population and wealth in hazard-prone areas is leading to an increased sensitivity of urban areas.

Construction of Map 7

For the elaboration of Map 7 regional GDP per capita data has been used to identify a high economic damage potential. The population density represents the economic as well as the social dimension. The environmental dimension is assessed by taking into account the extent of environmental assets affected by making use of an indicator of “naturalness”. The latter is based on classified CLC2000 data for Greece and CLC2006 data for all other countries.

The response capacity is based on national GDP per capita, addressing the country’s economic capacity to react to climate change and related short- and long-term consequences. In this methodological approach this indicator is reversed before being combined with the integrated sensitivity indicator.

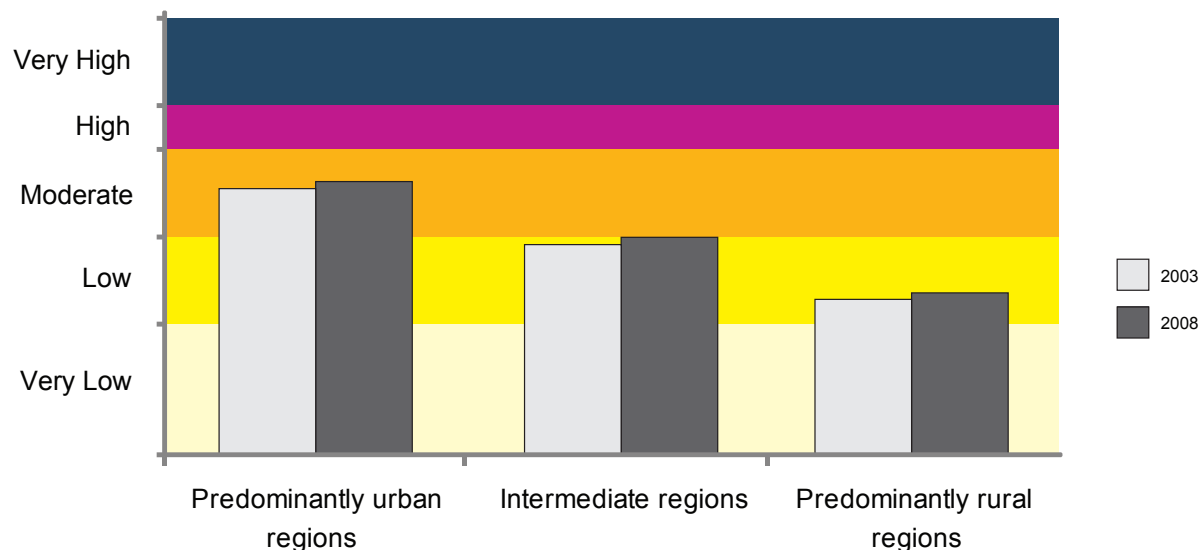
3 – Sensitivity and response capacity of European regions

During 2003 and 2008 the combined sensitivity and response capacity in different types of urban-rural regions increased just slightly. This can be observed for all types of considered regions (Figure 3).

Core of Europe with high sensitivity and response capacity. In addition to isolated cities, there are concentrations of high levels of combined sensitivity and response capacity in the core of Europe, from the UK to Benelux, Germany and Northern Italy. A second core with high levels is evident in Southern Poland (Silesia).

All these regions are highly sensitive to hazards as they are characterised by a high level of regional GDP per capita, in many cases probably as a result of a high level of industry and services with related high population densities. On the other hand these regions are located in countries which possess a high to very high national GDP which makes them better able to cope with, and respond to natural hazard events.

Figure 3 Average sensitivity and response capacity in different types of urban-rural regions



Construction of Figure 3

The presentation of different types of urban-rural regions considers population as well as regional and national GDP data for 2003 and 2008 allowing to identify changes. The indicator of "naturalness" is based for both years on the same CLC data.

4 – Vulnerability of European regions

The discussion on the vulnerability of regions combines exposure with sensitivity and response capacity presented in the previous chapters. These elements determine the possible impact that natural hazards and climate change may have on a region.

Natural hazards and climate change can increase existing vulnerabilities and deepen socio-economic imbalances in Europe.

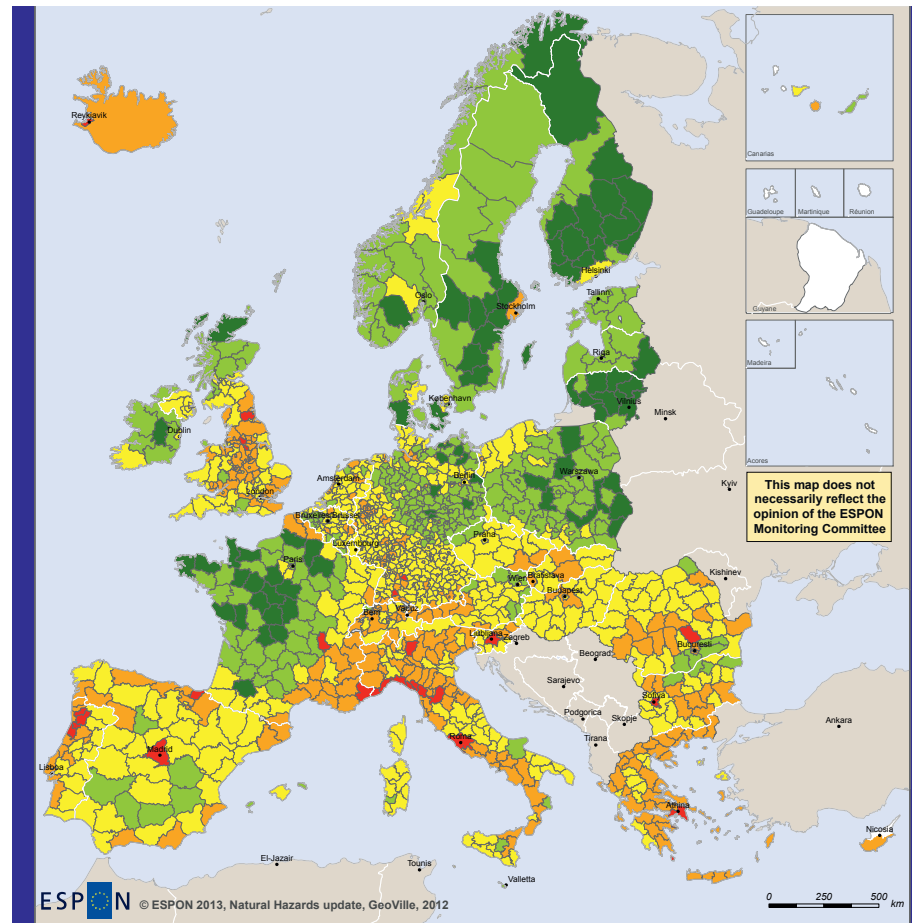
In the following, the regional patterns of vulnerabilities to natural hazards and the territorial diversity of climate change vulnerability, will be briefly discussed.

4.1 Vulnerability to natural hazards

Exposure potential has been combined with the sensitivity and response capacity to identify regions most vulnerable to natural hazards and their consequences (Map 8). The assessments of the exposure to natural hazards of European regions, the sensitivity and response capacity, and the vulnerability show similar key characteristics.

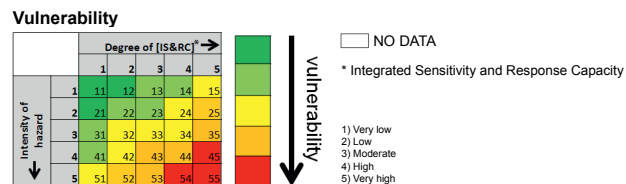
Regions which are most affected by the on-going financial and economic crisis in the South and South-East of Europe, are also the most vulnerable to climate change related natural hazard impacts.

Map 8 Vulnerability to natural hazards



EUROPEAN UNION
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Regional level: NUTS 3
 Source: ESPON 2013 Database
 Origin of data: GeoVille Environmental Services 2012
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Mediterranean at highest risk. The most vulnerable regions are located in the Mediterranean, including Spain, Portugal, Southern France, Italy, Greece, Romania and Bulgaria, where there is low response capacity. In addition large parts of UK and Iceland are highly vulnerable, whereas Nordic and Western European countries display low vulnerability potential due to the considerable response capacity in these regions.

Some more isolated vulnerable regions can be identified in the Alpine region, Germany, the Benelux and the Central East of Europe including the Czech Republic and Slovakia. These regions are all well developed with many assets threatened by specific hazard situations, for example winter storms, storm surges and river flooding in many German and Benelux regions.

The analysis of vulnerability for different types of urban-rural regions identifies predominantly urban regions as the ones most vulnerable in the European territory.

4.2 Vulnerability of specific types of regions

High vulnerability of cities. The impacts of extreme events including forest fires threatening cities, the flooding of the river Elbe (2002) or the urban flood in Copenhagen (2011), demonstrate the great vulnerability of cities to extreme weather events.

Population density and dependency on tourism are crucial factors. The following types of European regions are most vulnerable to natural hazards and climate change impacts:

- Cities and urban areas with high population density, where the problem of urban heat may become most relevant;
- Coastal regions with high populations, in particular those with high dependency on summer tourism;
- Mountain regions with high dependence on winter and summer tourism;
- Lowland regions exposed to river flooding;
- South and East European regions exhibiting low response capacity and threatened by climate-related hazards.

Regions having high exposure to natural hazards and climate change and low capacities to respond are most in need of action. Increases in population, economic wealth and human activity, leading to rising damage costs, are defining the need for additional remedial actions. However, changes in climate may also raise new opportunities for the territorial development of regions, although in order to make use of these opportunities, smart policy responses are required.

Territorial development bridges existing governmental levels and sectoral agendas, for example by providing direct linkage from the policy provisions of Europe 2020 to the local level. In particular, the principle of sustainable development, that provides a conceptual framework relating social, economic and environmental concerns, forms an important vehicle for policy definition and delivery within the framework of territorial development.

Example: Vulnerability of people and territories

The vulnerability of people and territories throughout Europe shows great diversity, as illustrated by the disasters occurring during the past decade. When the heat waves scorched France and other countries in the summer of 2003, most of the fatalities were elderly people. Many of them lived alone in flats not able to cope with the heat. The UK floods of 2007 affected a disproportionate number of poorer people living in flood-prone areas. A lot of the deaths from flooding in Romania and other Eastern European countries occurred in rural areas where flood control and defences were inadequate.

5 – Management of climate change and natural hazard risks

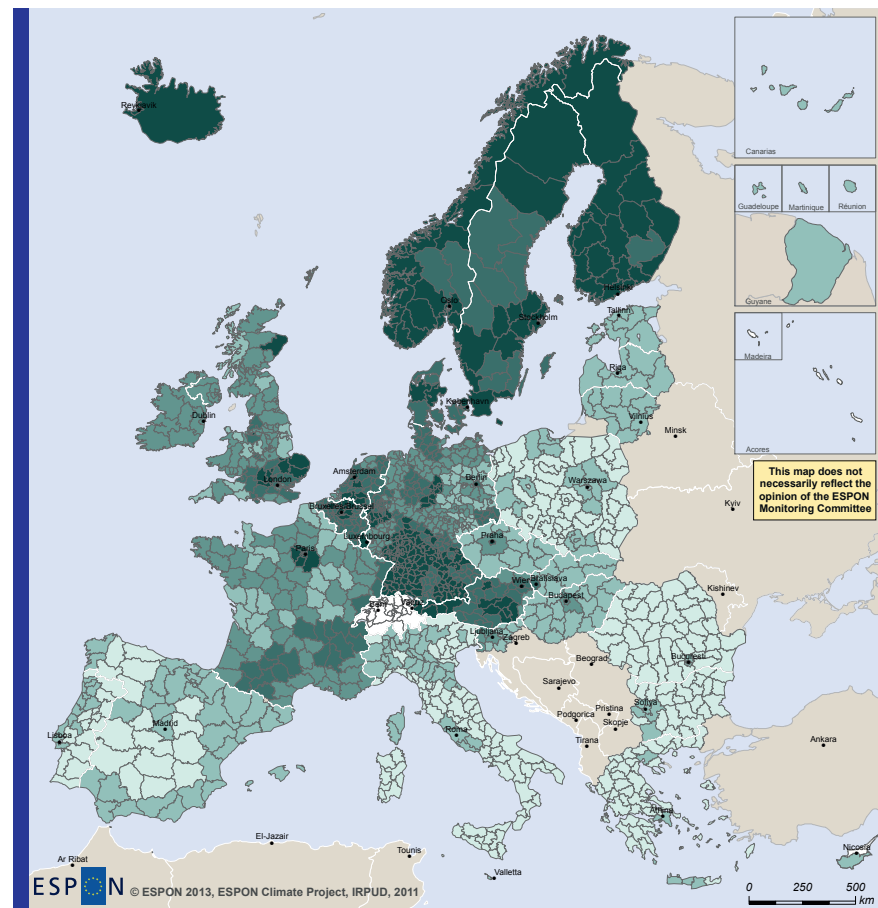
Besides the challenges that need to be faced with regard to climate change also new opportunities for the European territory can be highlighted. Following the adaptive and mitigation capacity of the European territory is discussed. Relevant policy responses are outlined and a number of adaptation measures are presented concerning policy provisions for specific types of regions.

5.1 Adaptation and mitigation policy responses

The starting point for adaptation and mitigation policies concerns regional and territorial differences. The necessity is to seek territorially differentiated strategies.

Adaptation and mitigation policy responses can reduce damage costs. Policy priorities include provision of the fullest protection to European citizens and their property, and the maintenance of social and economic capital. Against this backdrop adaptation response and mitigation capacities are viewed as critical elements necessary to minimise potential further territorial imbalances across Europe. These two elements are crosscutting issues, affecting policies related to disaster risk management, but also other EU policies such as Cohesion policy, Common agriculture policy or environmental policies.

Map 9 Adaptive capacity of European regions to climate change



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Regional Level: NUTS 3
Source: ESPON 2013 Database
Origin of data: Aalto University YTK, GISIS 2006,
ESPON Database 2006, Eurostat 2010, NSIS 2010,
EEA 2006, FSD 2010, Massey & Bergsma 2009, World Bank 2010
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Overall capacity to adapt to climate change

- highest capacity
- high capacity
- medium capacity
- low capacity
- lowest capacity
- NO DATA

Overall adaptive capacity towards climate change classified by quintiles.

The overall adaptive capacity was calculated as weighted combination of economic capacity (weight 0.21), infrastructural 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.

Definition of adaptive capacity

In line with the IPCC (2007) definition, adaptive capacity describes a society's ability to adjust to climate change, moderate potential damages, take advantage of opportunities or to cope with the consequences.

While adaptation is seen as a response strategy to climate change, adaptive capacity does not necessarily lead to adaptation measures being designed or implemented. These measures, though, can produce mitigation benefits while sustaining production and growth.

The adaptive capacity of European regions is highly differentiated (Map 9). Peripheral regions in the East and South have a much lower level of adaptive capacity than Nordic countries and regions in the core of Europe.

Construction of Map 9

The assessment of the adaptive capacity to climate change was divided into five dimensions, economic resources, institutions, infrastructure, knowledge and awareness as well as technology. For each dimension several indicators were identified, classified into five classes and combined in an average score. Using the results from a Delphi survey the weighted scores of the five dimensions were added up to the aggregate adaptive capacity score for each NUTS 3 region.

Mitigation capacity of European regions. Regions that have low mitigation capacity are mostly located in Eastern Europe as well as in Scotland and Portugal.

Definition of mitigation capacity

Mitigation capacity addresses structures to reduce human contributions to climate change or triggers for natural hazards. According to the IPCC (2007) mitigation includes strategies to reduce greenhouse gas sources as well as emissions and to enhance greenhouse gas sinks.

Regions that have high emissions and low mitigation capacity are of course the most crucial in terms of the reduction of greenhouse gas emissions. These regions can be found in Eastern Europe, the UK and Ireland. Also, some regions in Southern Italy fall into this category.

These regions are performing less well with regard to the EU competitiveness indicators. A low capacity for mitigation implies vulnerability to fluctuations in energy cost and security, and as a result a negative impact on competitiveness. Disparities in mitigation capacity, and its crucial role in the future competitiveness of Europe are generally acknowledged.

Of relevance for all regions is that the development of green and carbon-neutral technologies not only reduces greenhouse gas emissions but also provides new market opportunities.

New development opportunities coming up. Despite the challenges identified above, new development opportunities can be identified in respect of climate change. In the Alpine region, for example, such new development opportunities are mostly related to tourism, for adaptation these include diversification of the tourism industry, and for mitigation the development of eco and climate friendly tourist facilities. In other regions, a raise in temperature opens for growing new crops, such as wine in southern UK.

Support of Europe's competitiveness. If adaptation and mitigation response capacity is fully utilised, it will contribute to the competitiveness of the EU in the global market. The diversity of climatic characteristics in European regions permits a degree of economic flexibility. This will support keeping the EU's global position in relation to climate-sensitive economic sectors as for example summer and winter tourism.

Additional benefits might include opening of new shipping routes in the Arctic, enhanced forest growth, higher potential for electricity from hydro-power, lower energy consumption due to heating reductions and additional summer tourism in Northern Europe.

Typically, new opportunities introduce additional challenges with new burdens on the environment or economy. It is therefore of utmost importance to identify smart ways to make use of the opportunities arising to support a cohesive development of the European territory.

Territorial diversity requires place-based responses.

Analysis of the territorial differentiation of impacts provides the starting point for specification of future policy responses, including those addressing adaptation to, and mitigation of natural hazards risk and climate change. On this basis, tailor-made, place-based response options can be developed by municipalities and regions which permit engagement with regionally specific patterns of vulnerability.

Place-based responses benefit from integrated multi-level strategies. New policy responses to counter the threat of natural hazards and climate change are engaging all levels of governance. Multi-level strategies link European and local levels deploying integrated risk management, together with place-based policy development and implementation.

Harmonisation of data is key. In addition to improving the information base on past events, there is a need for further harmonisation of the information base. A particular focus when dealing with climate change challenges and natural hazard is therefore the development of similar approaches to vulnerability and risk assessment across Europe. The Floods Directive serves as a good example where this approach has already been implemented, involving all levels of governance.

5.2 Integrated risk management and natural hazards

Integrated risk management as framework for action.

A fundamental complement to the mobilisation of multi-level governance forces and resources in support of natural hazards response and mitigation measures is the deployment of integrated and holistic assessments and policy responses. Indeed integrated risk management and policy making provides an essential framework for the articulation of multi-level governance policy delivery.

Within integrated risk management, relevant elements including prevention (i.e. mitigation), preparedness (i.e. adaptation), response and recovery, is taken into consideration when dealing with any type of natural hazard risk. Priorities for development include enhancement of early warning systems, campaigns to raise public awareness, implementation of evacuation procedures and decision support tools.

Involvement of different groups of stakeholders is essential. Furthermore, effective integrated risk management strategies rely on the involvement of all potential stakeholders. This covers among others national, regional and local administrations, the scientific community, the private sector, for example insurance companies and citizens. Every stakeholder should contribute to measures and activities according to their own capacities and skills.

5.3 Towards integrated adaptation strategies

A range of concrete initiatives have taken place since 2009 when the White Paper on adaptation to climate change was published. The European Commission initiated various actions to integrate and mainstream adaptation into EU sectoral policies including in addition to natural hazard risk reduction, examples related to coastal areas, agriculture, infrastructure and urban environment.

The policy relevance of adaptation strategies is further outlined by the European Commission in “An EU Strategy on Adaptation to Climate Change” published in 2013. The first action of the EU Strategy is to “Encourage all Member States to adopt comprehensive adaptation strategies”. Furthermore it is envisaged to develop by 2014 an adaptation preparedness scoreboard, identifying key indicators for measuring Member States’ level of readiness.

Local and regional authorities should be ready to act. Synergies and trade-offs between adaptation and mitigation are a growing concern for local and regional authorities preparing strategies and developing guidelines regarding adaptation and mitigation. Joint adaptation and mitigation strategies at the local and regional levels are increasingly likely to focus on the relationship between the two.

In this respect the European Commission is promoting urban adaptation strategies. They are supporting capacity building and providing assistance for cities in developing and implementing adaptation strategies via the project “Adaptation Strategies for European Cities”. This project ends in summer 2013 and has a strong focus on exchanging knowledge and identifying good practices. Twenty-one cities are involved with the project, as peers, trainees and adaptation pilots, setting an example for other European cities.

Knowledge of local conditions is an advantage. Cities are in a unique position to develop tailored policy responses to natural hazards and climate change impacts. Local stakeholders have first-hand knowledge of conditions of cities and can develop proactive strategies in response to climate change. Local authorities can work together with agencies, the private sector and community organisations to develop new institutional models for local adaptation measures.

As regards local and regional level decision-making it is also essential to remember that the regional level is influenced by policy initiatives taken at other levels of governance, and this is also true with regard to mitigation and adaptation measures.

Diverse financial and communicative instruments available. Local actions might for example focus on the provision of local emergency plans or infrastructure resilient to climate change, the allocation of municipal resources or raising of other funds or the involvement

of the civil society and private actors. The regional level might provide incentives and funding to support activities on the local level, while the national level provides a supportive legal framework. European actions might cover inclusion of urban adaptation needs into European policies or the coordination of knowledge exchange across national borders.

Linking relevant elements is essential. Central to the development of an integrated approach at the European level is the link between the management of natural hazard risks and climate change adaptation and mitigation measures. These two need to be seen in relation to socio-economic development, as acknowledged by a wide range of leading policy documents and instruments, including Europe 2020, Territorial Agenda 2020 and the European Cohesion policy post 2014 (CSF Funds).

EU Cohesion policy can ensure that the most disadvantaged regions have access to support in order to balance and harmonize differences in the regionally varied patterns of vulnerability. A challenge for future Cohesion policy is to capture that the alignment of major environmental drivers of change, as for example natural processes, may reinforce each other and have medium- to long-term influence.

5.4 Territorially differentiated adaptation strategies

Specific types of regions face diverse challenges and adaptation recommendations for different types of regions can be presented (Table 1). It can be identified that highly vulnerable territories in South-East Europe are not restricted to specific types of regions but include several types. Substantial efforts and investments are needed in order to respond to the identified natural hazards and climate change impacts evident in the different regional contexts of the European territory.

The challenge ahead is focused on the development of comparable approaches to risk assessment across Europe. At the same time it needs to be acknowledged that territorially defined and differentiated policies addressing natural hazard and climate change risks are fundamentally place-based, and local level decision making is therefore important. If the territorial approach is not incorporated at national and sub-national levels, challenges are likely to emerge between local planning and national policy making.

It is essential to pursue effective deployment of adaptation and mitigation. These actions need to be targeted by territorially differentiated policies, noting in particular the special needs of South and South-East Europe.

5 – Management of climate change and natural hazard risks

Table 1 Adaptation recommendations for different types of regions

Type of region	Impact / adaptive capacity / vulnerability	Adaptation recommendations
Overall	Most Mediterranean and South-East European regions have highest vulnerability due to high impact and low adaptive capacity. Especially problematic: coastal and metropolitan regions in Southern Europe, tourist regions along Mediterranean and in the Alps.	<ul style="list-style-type: none"> • Territorial development, especially at local and regional scales, is central to the reduction of vulnerabilities. • Land use regulations, setting for example limits to the expansion of urban and tourist developments are envisaged as a mitigation tool or as adaptation. • New forms of governance may have to be developed in order to avoid excessive dependency on new and costly water technologies.
Metropolitan/urban regions	<p><u>Generally:</u> High impact due to concentration of residents and assets, but low vulnerability due to high response capacity.</p> <p><u>Problematic regions:</u> Metropolitan regions along (especially Southern- European) coasts, in the Alps and in South-East Europe have high vulnerability due to low adaptive capacity.</p>	<ul style="list-style-type: none"> • There is a general need for resilience in terms of natural hazards and climate change. A widespread agreement on territorial visions can be identified, that is characterised by following elements: Efficiency, Diversity, Redundancy, Robustness. • Adaptation needs should be considered for brownfield development and urban planning.
Rural regions	<p><u>Generally:</u> Low to high impact.</p> <p><u>Problematic regions:</u> Rural areas in South-East Europe (hotter & drier climate) due to low adaptive capacity.</p>	<ul style="list-style-type: none"> • Climate change as such is not a specific problem for rural regions. • The agricultural sector is normally able to adapt to a changing climate and may even benefit (longer vegetation period) except in those areas where water shortage becomes more and more an issue.
Sparsely populated regions	<p><u>Problematic regions:</u> Interior of Spain negative impact due to drought (hotter & drier climate). Scandinavia and Scotland negative impact due to more precipitation (river flooding, flash floods) but agricultural benefits due to warmer climate.</p>	<ul style="list-style-type: none"> • Improving their accessibility would support their response capacity.

5 – Management of climate change and natural hazard risks

Type of region	Impact / adaptive capacity / vulnerability	Adaptation recommendations
Border regions	<p><u>Generally:</u> Big disparities between border regions of one cross-border corridor due to different sensitivities (population density, settlement patterns, economic development) and, especially, differences in response capacity.</p>	<ul style="list-style-type: none"> • Integrative development strategies which balance the challenge of climate change with other issues such as demographic change, economic development and environmental issues.
Mountain regions	<p><u>Generally:</u> Medium to high impact and vulnerability. Mountain regions are particularly prone to a manifold of natural hazards which are triggered by climate change. Moreover, several mountain areas suffer from adverse demographic changes.</p> <p><u>Problematic regions:</u> Especially mountains in South-East Europe, Greece, Spain, southern side of Alps.</p>	<ul style="list-style-type: none"> • A sound assessment basis for hazard and risk mapping is needed, ideally coordinated among neighbouring states. • Integrated development strategies are useful for coordinating adaptation to climate with other issue such as tourism and nature protection.
Coastal regions	<p><u>Generally:</u> Mostly medium to high impact due to sea level and related effects (storm surges), but also economic dependency from tourism.</p>	<ul style="list-style-type: none"> • Not only the improvement of coastal defense systems, but also adjusted settlement restrictions according to the expected impact have to be discussed. • For some coastlines in the North, tourist development strategies become more and more relevant due to the projected increase in tourist comfort levels.
Islands	<p><u>Generally:</u> Severe impacts in Mediterranean and Atlantic islands. Particularly those islands in the South which are depended on tourism and agriculture may have a high impact.</p> <p><u>Problematic regions:</u> Islands in Mediterranean due to generally lower adaptive capacity (thus higher vulnerability).</p>	<ul style="list-style-type: none"> • A diversification of economic activities would enhance the resilience of islands in terms of natural hazards and climate change. • Supporting less climate sensitive activities would also foster the rehabilitation of the island's environment which is often under significant stress.



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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.

ESPON shall support Cohesion Policy development with European-wide comparable information, evidence, analyses and scenarios on framework conditions for the development of regions, cities and larger territories. In doing so, it shall facilitate the mobilisation of territorial capital and development opportunities, contributing to improving

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