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Natural and Technological Hazards and Risks Affecting the Spatial Development of European Regions

Edited by Philipp Schmidt-Thomé

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Philipp Schmidt-Thomé

This volume is based on peer reviewed articles that reflect the results of the ESPON 1.3.1 project
" The Spatial Effects and Management of Natural and Technological Hazards in Europe"

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Natural and technological hazards influence spatial development. Displaying spatial patterns of natural and technological hazards on a regional level, including possible impacts of climate change on hydro-meteorological hazards, delineates potential obstacles and challenges to future spatial development.

The European Spatial Planning Observation Network (ESPON) requested spatial patterns and territorial trends of hazards and risks covering the European Union, its accession and associated countries. The approach presented here uses results of international hazard research, harmonizing and combining those with an own methodology to display comparable information over the entire project. The natural and technological hazards relevant for spatial development were selected by specified risk schemes, and a so-called Spatial Filter was applied to select hazards and risks relevant for spatial planning concerns.

Since the importance of hazards differs over the territory and according to the perception of kazards and resulting risk, a weighting system was used to identify the spatial relevance of each hazard from a European perspective. Before developing an aggregated hazard map of Europe, the weighting method was tested in several case study areas.

The resulting aggregated hazard map shows a pattern of high and very high hazardous areas covering parts of central Europe, reaching into the Iberian Peninsula and the United Kingdom and scattering into central-eastern European countries before turning southwards through EU accession countries into Greece. The analysis of hazard cluster maps shows that certain areas of Europe can be associated with particular hazard agglomerations.

Risk is defined as a function of the hazard potential and the vulnerability. The integrated European vulnerability is based on a weighted combination of population density, gross domestic product (GDP – national and regional) and fragmented natural areas. The resulting aggregated risk map reveals a similar pattern in the medium risk as in the high and very high hazard areas, while the highest risk density is found in the “Pentagon” area.

Finally, spatial planning responses and policy recommendations on the management of potential hazard and risk impacts on regional development are elaborated.

Key words: *natural hazards, technological hazards, regional planning vulnerability, risk assessment, spatial planning, regional planning Europe*

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FOREWORD

This volume describes the first attempt to obtain a spatial overview of natural and technological hazards that pose challenges for sustainable development in Europe. European regions are exposed to hazards in varying degrees, and with different vulnerabilities, thus placing them in different risk positions. The EU Policy instruments have the potential to contribute to even out these differences as a matter of European solidarity, and therefore risk management should be understood as an important task for the cohesion policy. Consequently, stronger inclusion of risks related to natural and technological hazards in EU policies is needed.

The volume is based on the final report of the European Spatial Planning Observation Network's (ESPON) thematic project 1.3.1 "The spatial effects and management of natural and technological hazards in general and in relation to climate change" (ESPON Hazards project). The project was conducted from December 2002 to March 2005 within the framework of the ESPON Programme, partly financed by the ERDF through the INTERREG III Programme. The full reports of the project and more background information on the ESPON Programme can be downloaded from the ESPON website, www.espon.lu. The project's own website also displays the final report, selected hazard and risk maps as well as this publication under www.gtk.fi/projects/espon.

The volume is composed of several single articles that reflect the research of the authors who contributed to the map making and reporting of the ESPON 1.3.1 hazards project, and thus to developing a first integrated hazard and risk overview on the European territory.

The project had to display all its results on the 3rd level of the Nomenclature of Territorial Units for Statistics (NUTS) of the ESPON space, EU 27+2. The ESPON space covers the EU Member States, its applicant countries (Bulgaria and Romania) and associated countries (Norway and Switzerland). The approach was that all hazards had to be developed with harmonized data sets for all NUTS 3 regions of the ESPON space to maintain the comparability over the entire project area, also ensuring that the results can be merged with those of other ESPON projects. Since hazards do not respect political boundaries, this approach leads to potential inaccuracies, as sometimes hazards are displayed too exaggerated over certain, meanwhile other hazards might be displayed with a too low magnitude in other areas.

The large project space that had to be covered with comparable data sets also leads to a rather generalised display of hazards. Often preliminary data sets had to be used. Eventhough for many areas better data sets exist, these cover only parts of the project area and were thus not applicable for this project. Therefore the results displayed here are a first approach that should be developed further with better data sets and data coverage, longer project duration and sufficient funds. The authors hope to contribute to the discussion on hazards, risks and spatial development in Europe, which are topics of growing importance.

Philipp Schmidt-Thomé, January 2006

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SPATIAL RELEVANCE OF NATURAL AND TECHNOLOGICAL HAZARDS

by
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Fleischhauer, M. 2006. Spatial relevance of natural and technological hazards. Natural and technological hazards and risks affecting the spatial development of European regions. *Geological Survey of Finland, Special Paper 42,* 7–16, 2 figures, 5 tables.

Whenever dealing with natural and technological hazards in spatial respect, the question is which of the existing hazards are of relevance in such a spatial context. This article introduces selection criteria for spatially relevant risks. These criteria are elements of a "spatial filter" which is only passed by those hazards that are of relevance in the context of the European Spatial Planning Observation Network (ESPON). Finally, the selected hazards are classified according to their climate change relevance because the effect of climate change on hazards is a major task in the ESPON project 1.3.1.

Key words: natural hazards, technological hazards, classification, climate change, spatial planning, regional planning, urban planning

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1 INTRODUCTION

The range of hazards that may effect the development of municipalities and regions and the livelihood of their inhabitants is wide and comprises the possibility of hazardous events such as epidemics and wars, river flooding and nuclear incidents or smoking and traffic accidents. However, the question is which of the existing hazards are of relevance in the context of the European Spatial Planning Observation Network (ESPON), which aims to diagnosis the principle territorial trends in Europe and improving spatial planning policies as well as the spatial co-ordination of sectoral policies.

The question of which hazards are relevant in the ESPON context shall be answered by introducing selection criteria for spatially relevant risks. The selection of hazards is done in two steps:

1. *Risk type:* First, a list of possible hazards in Europe is compiled. These hazards and the risks they produce are characterised based on certain criteria (see below). In this step, a first group of risks (and with them the related hazards) is excluded.
2. *Spatial relevance:* In a second step, the spatial relevance of the hazards is assessed. Only those hazards that fulfil certain spatial criteria will be further considered (see below).

Finally, the selected hazards are classified according to their climate change relevance as the effect of climate change on hazards is a major task in the ESPON project 1.3.1.

2 FIRST STEP OF HAZARD SELECTION: RISK TYPE CRITERIA

First, hazards and the risks they induce are categorised and typologised. The logic behind this is to define which risk types are and are not relevant in the ESPON context. Thus, all hazards that are assigned to certain non-relevant risk types can be excluded.

The following typology focuses on the risk perspective. Risks emerge at the intersection of two opposing forces: the processes generating vulnerability on one hand, and the physical exposure to a hazard on the other. The risk of disaster is the result of hazard plus vulnerability. Thus, risks can be understood as a result of certain “elements of risk” (Blaikie et al. 1994, 22ff; Hewitt 1997, 24ff; Fleischhauer 2004, 50).

The German Advisory Council on Global Change (WBGU) suggests the following criteria (Table 1) as a basis for the classification and characterisation of risks. On this basis, risks can be classified into normal, transitional and prohibited areas of risk.

Risks in the *normal area* are characterised as follows (WBGU 2000, 42):

- Low uncertainty of both the probability of occurrence and the associated magnitude of damage,
- in total, a small catastrophic potential,
- in total, a low to medium probability of occurrence,

Table 1. Criteria for a typology of risks. Source: WBGU 2000, 55.

Criteria	Range of values
Probability of occurrence *P*	0 to approaching 1
Certainty of assessment of *P*	Low or high certainty of assessment of the probability of occurrence
Extent of damage *E*	0 to approaching infinity
Certainty of assessment of *E*	Low or high certainty of assessment of the extent of damage
Ubiquity	Local to global
Persistency	Short to very long removal period
Irreversibility	Damage not reversible to damage reversible
Delay effect	Short to very long time lag between triggering event and damage
Mobilisation potential	No political relevance to high political relevance

– low levels of persistency and ubiquity of risk sources or consequences,
– high reversibility of risk consequences should the damage occur,
– low statistical confidence intervals with respect to probability and magnitude of damage,
– no distinct distortions between the group that is exposed to the risk and the group to which opportunities and benefits accrue (distributional equity).

Risks in the *transitional* or *prohibited areas* have at least one of the following characteristics:

– uncertainty is high for all risk parameters,
– the damage potential is high,
– the probability of occurrence is high, approaching 1,
– the certainty of assessment is low, but there are reasons to assume that major damage is possible,
– persistency, ubiquity and irreversibility are particularly high, and reasons also must exist to assume that damage is possible,
– for reasons of perceived distributional injustice or other social and psychological factors, a major potential for mobilisation is to be expected (refusal, protest, resistance).

When risks reach areas that are significantly beyond everyday levels, either the 'transitional' or the 'prohibited area' is reached (Figure 1). In the transitional area, there is a possibility for risk-reducing measures that would shift an existing risk into the normal area. In the prohibited area, the risks are so severe that generally a ban should be imposed unless there is a consensus in society that these risks are to be accepted because of opportunities that as a result of the risk (WBGU 2000, 43f). Combining this display of risks with the criteria of Table 1 allows for the identification of different types of risks. The following risk types are characterised by the different values of probability of occurrence (and the certainty of its assessment), the extent of damage (and the certainty of its assessment) as well as extreme values of other criteria such as high persistence, long delay of consequences or mobilisation potential (Table 1). On this basis, it is possible to distinguish six different types of risks. In short, these types can be described as follows (names are taken from Greek mythology; WBGU 2000: 57 ff.; see Table 2):

– *Cyclops risk type:* For this type of risk, the probability of occurrence is largely unknown but the possible damage is quantifiable. These risks include natural disasters such as floods, drought or

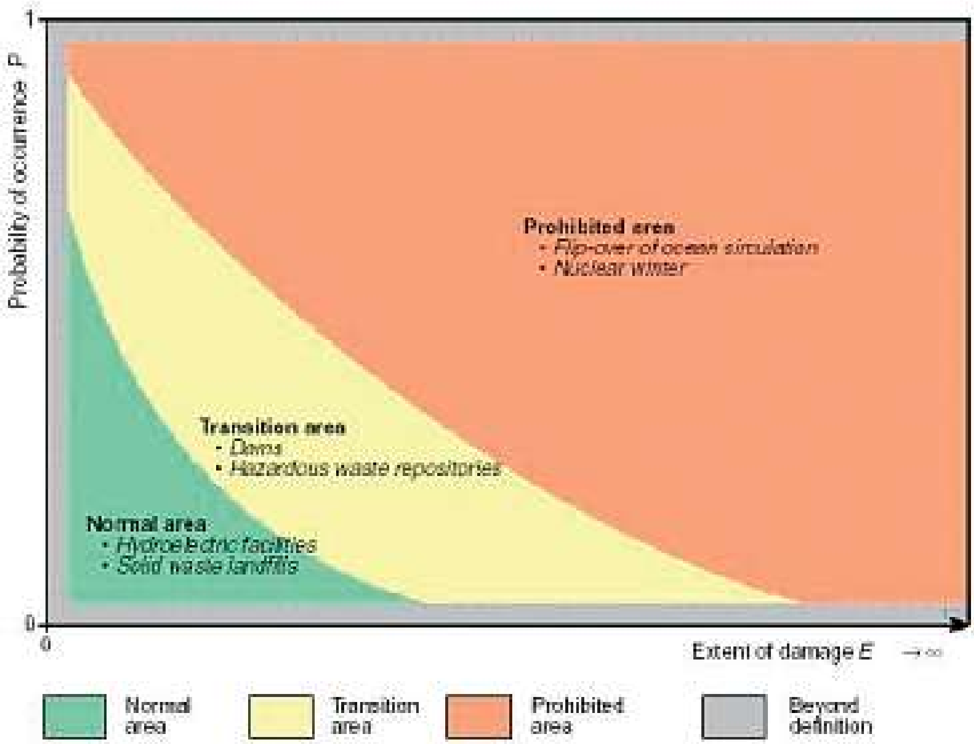

Fig. 1. Normal, transition and prohibited areas of risks. Source: WBGU 2000, 44.

Table 2. Overview of risk types: characterisation and substantive examples. Source: WBGU 2000, 62.

Risk type	Characterisation (*P* = probability of occurrence; *E* = extent of damage)
Cyclops	*P* is unknown; Reliability of estimation of *P* is unknown *E* is high; Certainty of assessment of *E* tends to be high
Damocles	*P* is low (approaching 0); Certainty of assessment of *P* is high *E* is high (approaching infinity); Certainty of assessment of *E* is high
Pythia	*P* is unknown; Certainty of assessment of *P* is unknown *E* is unknown (potentially high); Certainty of assessment of *E* is unknown
Pandora	*P* is unknown; Certainty of assessment of *P* is unknown *E* is unknown (only assumptions); Certainty of assessment of *E* is unknown Persistence is high (several generations)
Cassandra	*P* tends to be high; Certainty of assessment of *P* tends to be low *E* tends to be high; Certainty of assessment of *E* tends to be high Long delay of consequences
Medusa	*P* tends to be low; Certainty of assessment of *P* tends to be low *E* tends to be low (exposure high); Certainty of assessment of *E* tends to be high Mobilisation potential is high

volcanic eruptions, epidemics or cancerogenic substances in low doses, and also the possible breakdown of the North Atlantic Stream due to a collapse of the thermohaline ocean circulation, caused by anthropogenic climate change.

– *Damocles risk type:* In this type of risk, the possible damage can be very high, but the probability that it occurs is very low. In addition to meteorite impacts, many large-scale technologies can be assigned to this class of risk, such as major chemical works, mega-dams or nuclear power plants.
– *Pythia risk type:* In this risk type, both the possible damage and the probability of its occurrence are uncertain. Examples of Pythia class risks include genetic engineering interventions and the release of transgenic plants.
– *Pandora risk type:* The prime concern in the Pandora risk type is the global dispersal of persistent organic pollutants (POP), for example, chemical substances and their accumulation in organisms over time. In many cases, the consequences of these risks are still unknown or there are at best assumptions concerning their possible damaging effects. Examples of this risk type include DDT or endocrine disruptors.
– *Cassandra risk type:* In the Cassandra risk type, a relatively long period elapses between the causation and occurrence of harm. The long-term consequences of impending global climate change must be assigned to this risk class, as well as the destabilisation of terrestrial ecosystems due to the human induced change of biogeochemical cycles.
– *Medusa risk type:* In the case of Medusa type of risks, the public perceives hazards as being much larger than they really are. An example of this is the concern surrounding the cancerogenic effect of ionizing or electromagnetic radiation in low concentrations, which cannot be statistically proven.

These six types allow classifying the risks and attributing them to the normal, transition and prohibited areas of risk (Figure 2). The classification is not final as risks can evolve over time from one class to another. For example, further research and a longer period of experience or the use of risk management tools might move a Pythia type risk to the Cyclops type and from there towards the normal area (WBGU 2000, 63).

This typology of risks can serve as a rationale for selecting the hazards to be investigated within the ESPON Hazards project (see also Table 3, column “Risk type”):

– *Medusa and Cassandra:* The Medusa risk type is characterised by a high public sensitivity (mobilisation potential) and thus can be tackled with improved risk communication. Hence, it would not require a spatial planning response. Furthermore, this risk type is located in the “normal

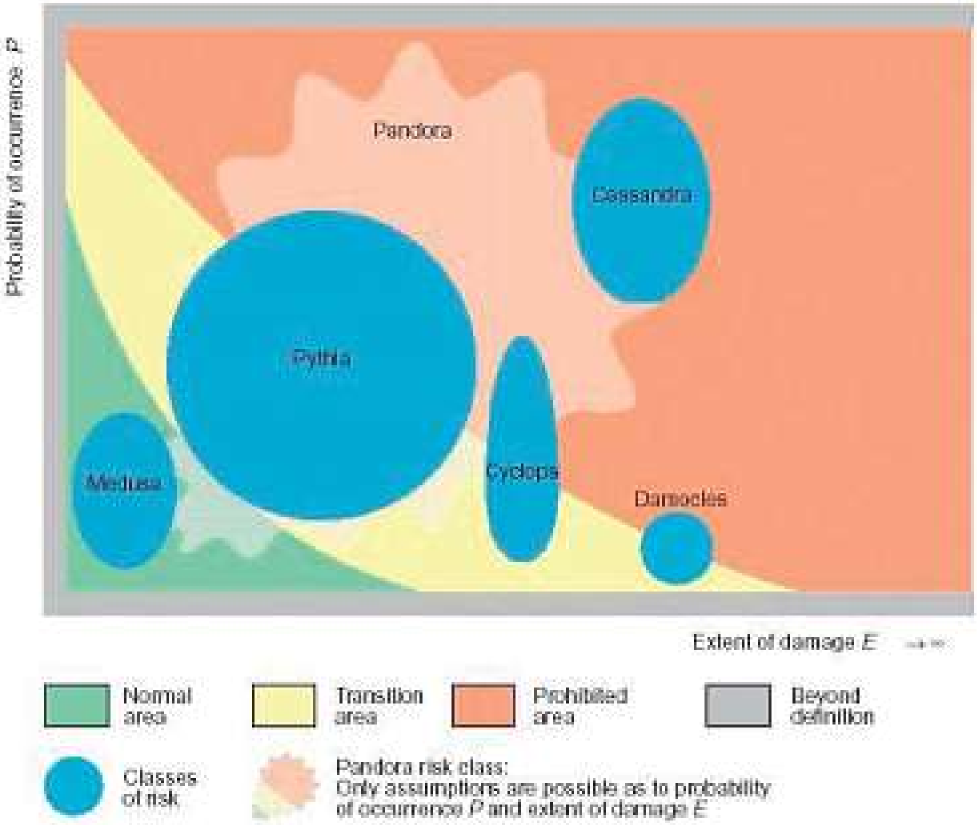

Fig. 2. Types of risk and their location in the normal, transition and prohibited areas. Source: WBGU 2000, 62.

area". The Cassandra risk type belongs to the prohibited risk area and is characterised by a long time lag in regard to consequences. Both risk types have to be discourse-based managed, which requires political decisions about social goals and thus cannot be solved by risk experts or regulators alone (Klinke & Renn 2002, 1089). Therefore, hazards that belong to the Medusa and Cassandra risk type are not considered in the ESPON 1.3.1 project, which mainly aims at spatial planning actions and responses.

– *Pythia and Pandora:* These types of risk mainly belong to the prohibited risk area and are characterised by a high degree of uncertainty with regard to probability and damage potential. They belong to the precaution-based risk management category. The priority of risk management has to be the application of precautionary measures and the development of substitutes (Klinke & Renn 2002, 1088). These characteristics show that such types of risks cannot be tackled by risk management in terms of spatial planning responses (although they might have negative spatial effects) but by integrated political and societal measures. Therefore, the Pythia and Pandora risk types will not be further investigated within the ESPON 1.3.1 project.
– *Cyclops and Damocles:* Both risk types are characterised by rather high damage extents and also a high certainty of assessment of the damage extent. Both risk classes require the application of risk-based strategies and regulation. For the Damocles risk class, the main approach is to reduce the risk components to reduce the possible extent of disasters. For the Cyclops class, a mixture of risk-based and precautionary strategies is useful because the distribution of probabilities is relatively unknown (Klinke & Renn 2002, 1088). These risk management areas are those where spatial planning can unfold the effectiveness of its instruments. Therefore, only these risk types will be regarded as relevant in the ESPON 1.3.1 project.

The risks of long-term climate change belong to the Cassandra type of risks. Thus, the risk of climate change and its management will not be considered in this project. However, climate change influences the frequency and magnitude of several natural hazards like extreme weather events, floods or storms. These hazards belong to the Cyclops or Damocles risk types and are therefore considered in the ESPON Hazards project.

3 SECOND STEP OF HAZARD SELECTION: SPATIAL RELEVANCE

The categorisation of risks into certain types does not yet allow for the extraction of those risks from the great number of possible risks that are relevant for the ESPON 1.3.1 project. For example, murder, drug abuse or road accidents definitely belong to the main risks in Western societies. However, risks like these do not have any specific spatial relation, which means that their occurrence is not limited to some exclusive areas. Disasters like earthquakes, coastal and river floods or nuclear power plant accidents show that physical structures and regional development may be severely threatened by natural and technological hazards. All these conditions converge in particular places. Therefore, the second step for the selection of risks excludes non-spatial risks by a "spatial filter".

The *spatial filter* screens risks according to their spatial character. The spatial character is defined by spatial effects that might occur if a hazard turns into a disaster. Of course, *every* hazard has a spatial dimension (disasters take place somewhere). However, the occurrence of spatially relevant hazards is limited to a certain disaster area, which is regularly or irregularly prone to hazards (e.g. river flooding, storm surges, volcanic eruptions). Spatially non-relevant hazards occur more or less anywhere (e.g. flash floods, car accidents, meteorite impacts).

4 SELECTION OF SPATIALLY RELEVANT HAZARDS

Table 3 shows the results of the spatial filtering process. Only those hazards that have a specific spatial relevance will be further considered (+ = high spatial relevance or O = low but still existing spatial relevance) whereas hazards without spatial relevance (– = none) do not pass the filter (see Table 3, column "Spatial filter").

On the basis of the criteria discussed above, Table 4 lists the hazards that are relevant for the ESPON 1.3.1 project. Further, the indicators that are used in the hazards and risk assessment method in Chapter 5 are shown, the results of which are shown in Chapter 3.

Table 3. Evaluation and selection of risks on the basis of risk type and spatial filter. Source: Own elaboration.

Risks / Hazards	**Risk type** (first step of risk selection)				**Spatial filter** (second step of risk selection)	**Selection results (relevance for ESPON Hazards)**	
	Characterisation of risk			**Risk type**	Specific spatial relevance: + = high, o = low, – = none	**ESPON-rele-vance?**	**Reason for exclusion**
	Probability *P*	Extent of damage *E*	Extreme value of certain criteria				
Volcanic eruptions	unknown	high	---	Cyclops	+	yes	---
River floods	unknown	high	---	Cyclops	+	yes	---
Storm surges	unknown	high	---	Cyclops	+	yes	---
Tsunamis							
Avalanches	unknown	high	---	Cyclops	+	yes	---
Landslides	unknown	high	---	Cyclops	+	yes	---
Earthquakes	unknown	high	---	Cyclops	o	yes	---
Droughts	unknown	high	---	Cyclops	o	yes	---
Forest fires	unknown	high	---	Cyclops	o	yes	---
Winter and tropical storms	unknown	high	---	Cyclops	o	yes	---
Extreme temperatures (heat waves, cold waves)	unknown	high	---	Cyclops	o	yes	---
Hazards along transport networks	high	low	High ubiquity	Cyclops	–	no	Spatial filter
Hazards from the collapse of thermohaline circulation (breakdown of the North Atlantic Stream)	unknown	high	---	Cyclops	–	no	Spatial filter
Nuclear early warning systems and nuclear, biological and chemical weapons systems	unknown	high	---	Cyclops	–	no	Spatial filter
Epidemics (e.g. AIDS infection)	unknown	high	---	Cyclops	–	no	Spatial filter
Cancerogenic substances in low doses	unknown	high	---	Cyclops	–	no	Spatial filter
Mass development of anthropogenically influenced species	unknown	high	---	Cyclops	–	no	Spatial filter
Hazards from nuclear power plants	low	high	---	Damocles	+	yes	---
Major accident hazards	low	high	---	Damocles	+	yes	---
Hazards from oil processing, transport and storage	low	high	---	Damocles	o	yes	---
Air traffic hazards	low	high	---	Damocles	o	yes	---
Meteorite impacts	low	high	---	Damocles	–	no	Spatial filter
Terrorism, war, crime	unknown	unknown	---	Pythia	o	no	Risk type
Instability of the West Antarctic ice sheets	unknown	unknown	---	Pythia	o	no	Risk type
Self-reinforcing global warming (runaway greenhouse effect)	unknown	unknown	---	Pythia	–	no	Risk type
Release and putting into circulation of transgenic plants	unknown	unknown	---	Pythia	–	no	Risk type
BSE/nv-CJD infection	unknown	unknown	---	Pythia	–	no	Risk type
Certain genetic engineering interventions	unknown	unknown	---	Pythia	–	no	Risk type
Dispersal of persistent organic pollutants (POPs)	unknown	unknown	High persistence	Pandora	–	no	Risk type
Endocrine disruptors	unknown	unknown	High persistence	Pandora	–	no	Risk type
Long-term consequences of human-induced climate change	high	high	Long delay of consequences	Cassandra	o	no	Risk type
Destabilization of terrestrial ecosystems due to human induced change of biogeochemical cycles	high	high	Long delay of consequences	Cassandra	o	no	Risk type
Electromagnetic fields	low	low	High mobilisation potential	Medusa	o	no	Risk type

Table 4. Selected natural and technological hazards and indicators used in the ESPON 1.3.1 project. Source: Schmidt-Thomé 2005, 16.

Natural Hazards	**Indicators**
Avalanches	– Areas that have reported landslide/avalanche potential (derived from several sources)
Droughts	– Amount of observed droughts 1904–1995
Earthquakes	– Peak ground acceleration
Extreme temperatures	– Hot days – Heat waves (7-day maximum temperature) – Cold days – Cold waves (7-day minimum temperature)
River floods	– Large river flood event recurrence (1987–2003) (derived from several sources)
Forest fires	– Observed forest fires per 1000 km^2 (1997–2003) – Biogeographic+ regions
Landslides	– Questionnaire, expert opinion of geological surveys of Europe
Storm surges	– Approximate probability of storm surges
Tsunamis	– Areas that have experienced tsunamis
	– Areas in close vicinity to tectonically active zones
Winter and tropical storms	– Approximate probability of winter/tropicalstorms
Volcanic eruptions	– Known volcanic eruptions within the last 10,000 years
Technological hazards	**Indicators**
Air traffic hazards	– Civil commercial airports – Amount of passengers per year
Major accident hazards	– Number of chemical production plants per km^2 per NUTS3 region
Hazards from nuclear power plants	– Location of nuclear power plants – Distance from nuclear power plants, based on fallout experience of the Chernobyl accident
Oil production, processing, storage and transportation	– Sum of refineries, oil harbours and pipelines per NUTS3 region

5 SPATIAL RELEVANCE AND CLIMATE RELATION OF SELECTED HAZARDS

One of the main tasks of the ESPON 1.3.1 project is to assess the influence of climate change on hazards and their spatial impact. In the following, those hazards with relevance for the ESPON 1.3.1 project are structured along spatial relevance (criteria described above) and climate relation where the criteria is the influence of climatic factors on the natural hazards as shown in Table 4. The table shows that the seismicity related natural hazards (earthquakes and tsunamis) and the technological hazards especially do not have any climate relation.

In consequence, only some of the selected hazards are also important in the context of climate change. These hazards are shown in the grey shaded boxes. The influencing climate factors on natural hazards are as follows (see Bärring & Persson, Chapter 7, this volume and Schmidt-Thomé 2005, 106):

– *avalanches:* snowpack structure, temperature evolution/precipitation;
– *droughts:* precipitation, temperature/evaporation;
– *extreme temperatures:* temperature;
– *river floods:* excessive rainfall for an extended period, possibly in combination with snow melt;
– *forest fires:* precipitation, temperature/evaporation, wind;
– *landslides:* saturated soils (wet spells/heavy precipitation), thawing of mountain permafrost;
– *storm surges:* low pressure, windstorm, sea-level rise;
– *winter and tropical storms:* low pressure, atmospheric dynamics.

Table 5. Climate relation and spatial relevance of hazards; grey shaded boxes show climate change related hazards. Source: Based on Fleischhauer 2004, 118.

Climate relation / Spatial relevance	High	Medium	Low / non-existent
High	– Avalanches – River floods – Landslides	– Storm surges	– Volcanic eruptions – Hazards from nuclear power plants – Major accident hazards
Medium	– Droughts – Extreme temperatures – Forest fires	– Winter and tropical storms	– Earthquakes – Oil production, processing, storage and transportation – Air traffic hazards
Low / non-existent	---	---	---

6 SUMMARY AND CONCLUSION

This chapter has shown a way of dealing with a typical problem that appears whenever the topic of "risk" is of concern. As risk comprises a large variety of concepts and types, it has to clarified which risks are of relevance for the scientific questions that shall be answered or the problems that shall be solved. Therefore, selection criteria have to be defined to identify relevant risks.

For such a selection process, a two-step procedure was presented in this chapter. The first step consisted in a general, risk-type based selection whereas in the second step, specific criteria (spatial relevance) were used. This concept has also been used by the German Advisory Council on Global Change (WBGU) for screening globally relevant environmental risks (WBGU 2000, 48ff) and can also be applied in other contexts.

For the ESPON 1.3.1 project, only those risks that either affect spatial development or that can be affected by spatial planning were selected.

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NATURAL AND TECHNOLOGICAL HAZARD MAPS OF EUROPE

by
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Schmidt-Thomé, P. & Kallio, H. 2006. Natural and technological hazards and risks affecting the spatial development of European regions. *Geological Survey of Finland, Special Paper 42,* 17–63, 15 figures, 21 tables, 17 maps.

Hazards are natural extreme events or technological accident phenomena that can lead to threats and damages to the population, the environment and/or material assets. The origin of hazards can be purely natural (e.g. earthquakes) or technological (e.g. accidents in chemical production plants), as well as a mixture of both (e.g. sinking of an oil tanker in a winter storm and subsequent coastal pollution). All so-called natural hazards occur on a more or less regular basis, as they are phenomena that belong to natural processes. As part of natural processes, they do not pose any threat to the natural system itself, as nature is used to recovering and adapting to natural hazards. Technological hazards pose threats to human assets and nature, as they can have impacts that do not belong to natural processes. Also, technological hazards can have very long lasting unnatural effects (e.g. oil spills and nuclear fallouts). The ESPON Hazards project has developed a methodology to map spatially relevant natural and technological hazards in European regions, finally aggregating the hazards and combining them with vulnerability concepts to produce risk maps. The resulting map sets allow an overview of hazard and risk patterns potentially affecting the spatial development of the European Union and associated countries.

Keywords: natural hazards, geologic hazards, technological hazards, maps, risk assessment, spatial planning, Europe

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INTRODUCTION

This article presents the hazard and risk mapping methodology of the European Spatial Planning Observation Network's (ESPON) thematic project 1.3.1 "The spatial effects and management of natural and technological hazards in general and in relation to climate change" (ESPON Hazards project). The goal of the ESPON Hazards project was to identify those hazards that influence the spatial development of Europe and to identify hazard patterns and regional typologies. One target behind this approach is to support cohesion regional development in Europe, for example by reducing adverse effects of hazards. The selection of spatially relevant hazards is described by Fleischhauer 2006 (this volume).

The project had the task of developing all hazard and risk data sets on the third level of the Nomenclature of Territorial Units for Statistics (NUTS) of the ESPON space, EU 27+2; that is the EU member states, its accession countries (Bulgaria and Romania) and associated countries (Norway and Switzerland). The natural and technological hazards relevant for spatial planning aspects are thus displayed in these administrative regions of Europe, enabling comparison and cross analysis with other regional data of ESPON. The result is an overview of hazards and risks from a European perspective that displays the regions that are affected by hazards and not the exact hazard prone areas within these regions. It is important to keep in mind that hazards do not follow political boundaries and that data generated on the NUTS 3 level are generalized and statistically rough. This is especially the case considering the independence of the data sources and the coarse resolution of the data available on a European-wide scale. Since hazards, risks, catastrophes and disasters do not respect political boundaries, and a categorisation into administrative areas will always lead to generalisations or exaggerations, thus giving partially deviated images of reality.

1 NATURAL HAZARDS

The task of creating an aggregated hazard map of Europe required a consistent methodology; therefore all hazards, both natural and technological ones produced by the ESPON hazards project follow the same description type from *hazard characterisation, over risk management, a hazard map description to map analysis.* All hazard classifications follow the same scheme from *very low* to *very high hazard*. Ideally, the hazards are displayed in five classes (see Table 1). When this was not possible less classes were chosen, remaining in the same classification from very low to very high.

Table 1. Hazard classification.

Class	Hazard intensity
1	Very low
2	Low
3	Medium
4	High
5	Very high

Natural hazards are defined as extreme natural events that can cause damage. These extreme events occur in closed time spans of seconds or weeks, after which the initial state before the extreme event is reached again. Longer lasting processes, such as climate change and desertification, might have adverse regional impacts but do not belong to hazards as they occur over a long period of time and thus form part of general changes to the living environment. Most natural hazards arise from the natural physical processes operating in the Earth's interior, at its surface, or within its enclosing atmosphere.

1.1 Avalanches

Fig. 1. Avalanche in a research area in Vallée de la Sionne, 10.02.99. Source: Swiss Federal Institute for Snow and Avalanche Research (SLF).

Hazard characterisation

An avalanche is a mass of snow, ice and debris sliding down a mountainside. The parameters describing the possibility of having an avalanche comprise slope steepness, depth of snow cover, volume of weak layers in the snow (ice) cover, water saturation, and other effects (wind, seismic activities, etc.). According to a study of several hundred avalanches, 90% of avalanches with (fatal) accidents were triggered by the victims themselves, only 6% are of natural causes and 4% are of unknown causes (McCammon 2000).

Risk management

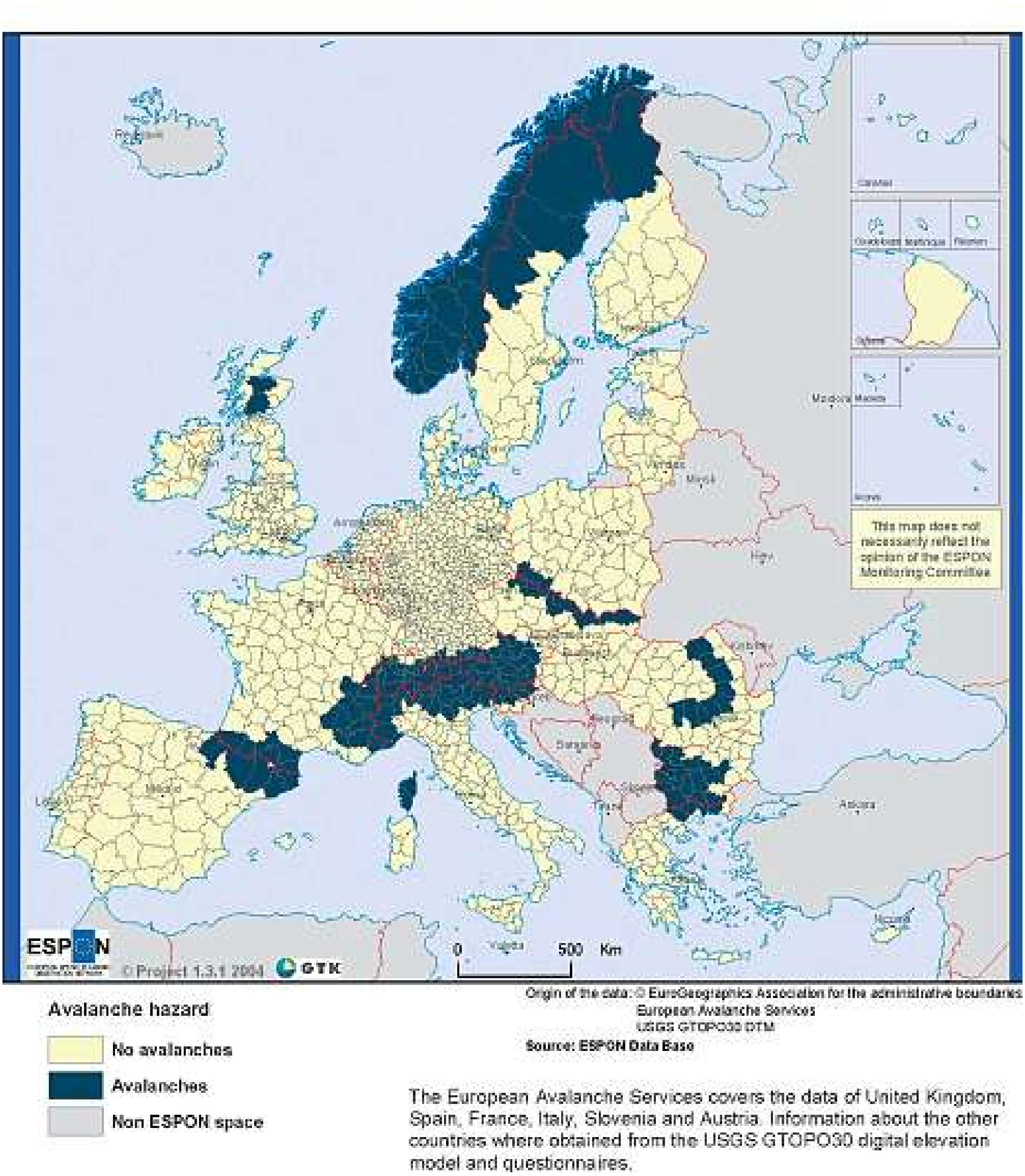
The European Avalanche Services maintains a website that includes regularly updated maps and reports on avalanches in the Alpine Regions and the Pyrenees. The website also displays many links to other avalanche information websites in Europe and overseas. Many tour operators and skiing resorts maintain their own websites with regularly updated information on the snow conditions and the avalanche hazard. Most European skiing and hiking areas have very detailed and strict avalanche surveillance and warning systems. In these skiing and hiking areas, the zones that are safe to use for recreational purposes are clearly marked with signs and maps. Most avalanche accidents in skiing and mountaineering areas therefore happen to persons that move out of the secure areas and have little knowledge or experience with the hazard, or that deliberately take the risk.

Avalanche hazard map

Avalanches are very local phenomena that occur only along certain slopes and valleys. The avalanche hazard map displays those NUTS 3 areas in which avalanches may occur. The map does not display a general local frequency or probability, as this is not feasible due to changing weather conditions. Thus, avalanche maps have to be updated locally and regularly. One must bear in mind that avalanches are a natural hazard that is restricted to valleys and slopes that are not representable on a European scaled NUTS 3 level map.

Table 2. Avalanche hazard classification.

Areas with no (or unknown) avalanche potential	1 Very low hazard
Areas with avalanche potential	5 Very high hazard



Map 1. Avalanche hazard.

Map analysis

All NUTS 3 regions with an avalanche hazard have major skiing resorts. Since people moving in avalanche-prone areas trigger most avalanches that include loss of human life, reliable data was difficult to obtain on avalanches in those mountain regions that are not major tourist areas. The avalanche hazard might therefore appear exaggerated in areas that have lower mountains and less snow than others, as it depicts areas with existing information on avalanches, for example Scotland (The Sport Scotland Avalanche Information Service). Areas that might bear higher possible avalanche hazards that do not have extensive tourism might not be represented. The map shows that the avalanche hazard is widespread among all European mountain regions famous for winter sport activities.

1.2 Droughts

Fig. 2. Dry clay in Crete. Source: Philipp Schmidt-Thomé 2003.

Hazard characterisation

Droughts are usually characterized into three types (Moneo & Iglesias 2004): 1) Meteorological droughts (levels of precipitation); 2) Hydrological droughts (water levels in rivers, lakes, reservoirs and aquifers); and 3) Agricultural droughts (availability of water for crops).

Since the ESPON Hazards project was not able to obtain comparable drought data on any of these drought types for the entire ESPON space, it was not possible to develop a drought indicator. Instead, data on scarcity of precipitation in large catchment areas were used to develop an indicator for drought potential (see map below) to point out the potential for drought hazards in European regions. It is also important to stress that it is assumed that spatial development is affected by the economic effects caused by any of the drought types mentioned above.

Droughts and long dry periods have led to serious power failures in Europe and as a result, to great economic losses in the industrial and tourism sectors. While most drought assessments concentrate on the effect on vegetation and estimated economic losses to agricultural production, drought risk should also consider the effects on the producing industry and service sector. The European countries' agricultural GDP share is well below 5%, and in most of the countries it is less than 3%. Therefore, in Europe drought impacts on the industry and service sector are more harmful to the economy than agricultural losses. The 2003 drought in Europe accounted for almost 1/3 of the economic natural hazard losses (Munich Re 2004).

The long-term drought effect on groundwater and surface water levels have a strong impact not only on agriculture but also on power production. For example nuclear power plants might have to run on lower production rates because their cooling systems depend on rivers or lakes. Most of the hydro power plants in areas affected by droughts suffer from reduced energy production due to lower water levels. This is especially crucial for the economy of a country like Norway, which depends on hydropower (Cherry et al. 2000). Other countries in northern Europe that have a high consumption of hydropower also experience the economic effects of rising electricity prices during droughts (Acher 2002). Droughts usually have long-term impacts, as the water reservoirs, both surface and subsurface, need several rainy periods to be restored. A combination of drought and a heat wave is dreadful. The power support is not only getting shorter due to the drought effects mentioned above, it is also stressed by the need for cooling systems that also demand a lot of energy. Additionally, power plants might have to shut down because the cooling water taken from lakes, rivers or the sea might be too warm to be used.

Risk management

The effects of droughts have to be analysed and assessed on a regional or local scale. While failing groundwater recharge over a certain period does not necessarily have long lasting ecological affects, an accumulation of many events over several years can affect the entire ecological system. It is also important to take the dependency of a groundwater system on annual recharges into account. Regions with very shallow aquifers require steady recharge while deeper and larger aquifers can cope more easily with drier years, simply because they store much more water. In Europe, the human impact on droughts is considerable. There are several examples of water resource mismanagement, such as over pumping of aquifers, sealing off of areas thus increasing surface runoff and restricting groundwater recharge, overuse of water in dry areas, and intensive agriculture in places where extensive agriculture would be more appropriate. Since climate conditions that lead to droughts are extremely difficult to predict and droughts are usually not recognizable until it they are already well advanced, the drought hazard can only be managed by the sustainable use of water resources. Water should be stored in times when it is abundantly available to ensure enough supply during a drought.

Map of precipitation deficits in regional basins 1904–1995 as potential drought indication

The heterogeneous topography, climate and vegetation of Europe make it very difficult to compare the drought hazard on European scale because agricultural droughts are dependent on local circumstances (vegetation types, plant water demands, etc.), and meteorological droughts might expand beyond areas of hydrological droughts. Hydrological droughts are those that could best describe the impact on power production and industry, which are the major reasons for economical damage by droughts.

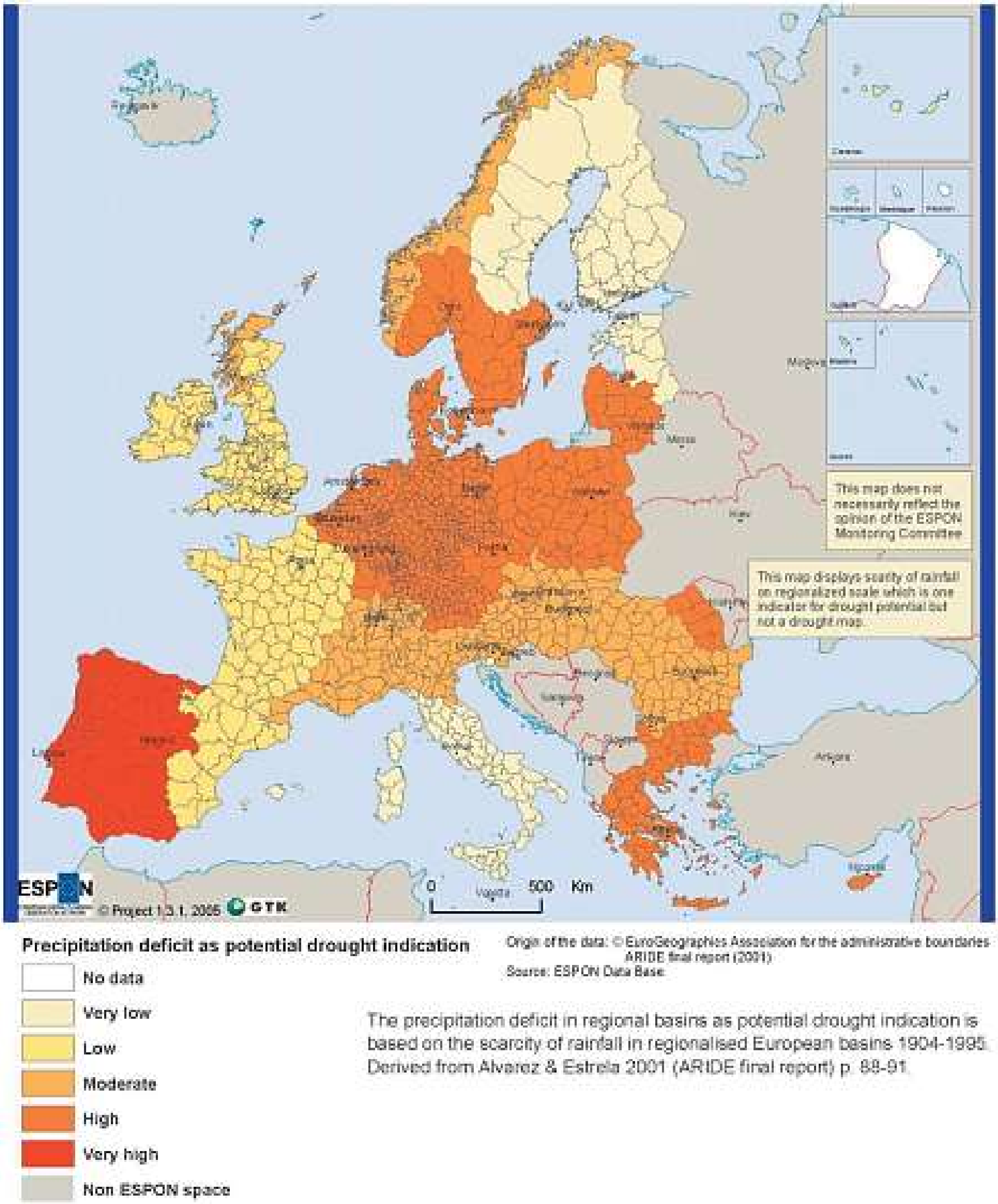
Since the ESPON Hazards project did not obtain the appropriate data sets for making such a hydrological drought map, it focussed on the report by Alvarez & Estrela (2001). This report presents a map of European regions based on a clustering process. A table in this report mentions large drought events in Europe based on scarcity of precipitation. Due to the non-availability of data, other drought aspects were not taken into account in this table. The ESPON Hazards project merged the table and the map and displays the resulting recorded droughts on the NUTS 3 level. This approximately 100 year long record does not predict future areas that might be hit by droughts. Since the map is based on historically reported drought events, the data accuracy is variable. Therefore, the map is applicable as a general overview map on past large drought events in Europe. The resulting potential drought hazard is calculated from the amount of recorded droughts per NUTS 3 level during the last century.

Table 3. Precipitation deficit as potential drought indication.

Amount of observed precipitation deficits 1904–1995	Class
2	1 Very Low
3–5 (no area with 4 droughts)	2 Low
6	3 Medium
7	4 High
8	5 Very high

Map analysis

The map shows interesting patterns of the precipitation deficit aspect on drought potential on European scale. For example, Norway has problems with water deficiency because the country's economy is strongly depending on hydropower. Even though Norway has some of the rainiest places in Europe, small negative deviations in precipitation can lead to energy problems because the water reservoirs are not refilled appropriately (Cherry et al. 2000). The map also shows that the Mediterranean area has a



Map 2. Precipitation deficit as a drought potential indicator.

wide variety of drought potentials. While Portugal and western Spain have the largest drought potential in Europe, eastern Spain appears to generally have a lower potential. Some areas in southern Europe that are usually associated with droughts appear less dramatic in this map. The reason for this lies in stronger local effects of agricultural droughts, as these might be partly related to the adequacy of agricultural systems and related water scarcity. A problem in this map is the severe jumps of two classes in some areas, like northern Europe. Also, southern Italy appears to have a low drought potential, even though areas with a higher drought potential surround it. The reason for this might be that the drought problem in southern Italy is not directly related to precipitation deficits but to other reasons not displayed here.

As mentioned above, the data and map shown here represent one indication for drought potential. The data are gathered over a long time period with scarce information displayed in clusters over European regions. Due to the existing limitations of the map, the results are not used as a basis for drought policy recommendations in general. The map shown here can only be used as one indicator of many in the drought hazard discussion and much more research is needed for the production of a European drought hazard map.

1.3 Earthquakes

Fig. 3. Earthquake in Athens 1999. Source: Michael Fardis.

Hazard characterisation

Earthquakes are seismic movements of the solid earth that are mainly caused by tectonic activities. Most of the world's earthquakes occur in areas where large tectonic plates meet but they may also occur within plates themselves. Earthquakes can also occur because of other impacts, such as the collapse of underground cavities. Human-induced explosions, like tunnelling works, can also create local earthquakes. Therefore, earthquakes can occur in all terrestrial and submarine areas. Earthquakes can also trigger other hazards, such as landslides, tsunamis and avalanches.

Risk management

Some of the oldest and most traditional settlement areas of the ESPON space lie in seismically highly active zones, for example in the Mediterranean area. Many of these settlements have been severely affected by earthquakes throughout human history, with high amounts of human casualties and losses of large parts of towns and cities. Nevertheless people have always resettled in the same places, and in fact there is no proof of a settlement that has been abandoned due to earthquake hazards. Since it seems not possible to relocate settlements because of seismic hazards, other precaution measures have to be taken. Minimization of the loss of life, property damage, as wellas social and economic disruption due to earthquakes depends on reliable estimates of the hazard. National, state, and local governments, and the general public require seismic hazard estimates for land use planning, improved building design and construction, including the adoption of building construction codes. The EN1998 Eurocode 8: “Design of structures for earthquake resistance” intends to regulate earthquake proof building design in Europe (Lubkowski & Duan 2001).

Earthquake hazard map

The peak ground acceleration data from the Global Seismic Hazard Assessment Project (GSHAP) were used to produce an earthquake hazard map for the whole of Europe. The GSHAP project was designed to provide global seismic hazard framework as a resource for any national or regional agency for further detailed studies. One of the main goals of GSHAP was to produce a homogeneous seismic hazard map for horizontal peak ground acceleration that is representative for stiff site conditions, the probability level of an occurrence that may exceed 10% within 50 years. The peak acceleration is the maximum acceleration experienced by the particle during the course of earthquake motion. Acceleration is chosen because the building codes prescribe how much horizontal force a building should be able to withstand during an earthquake. This force is related to the ground acceleration (g).

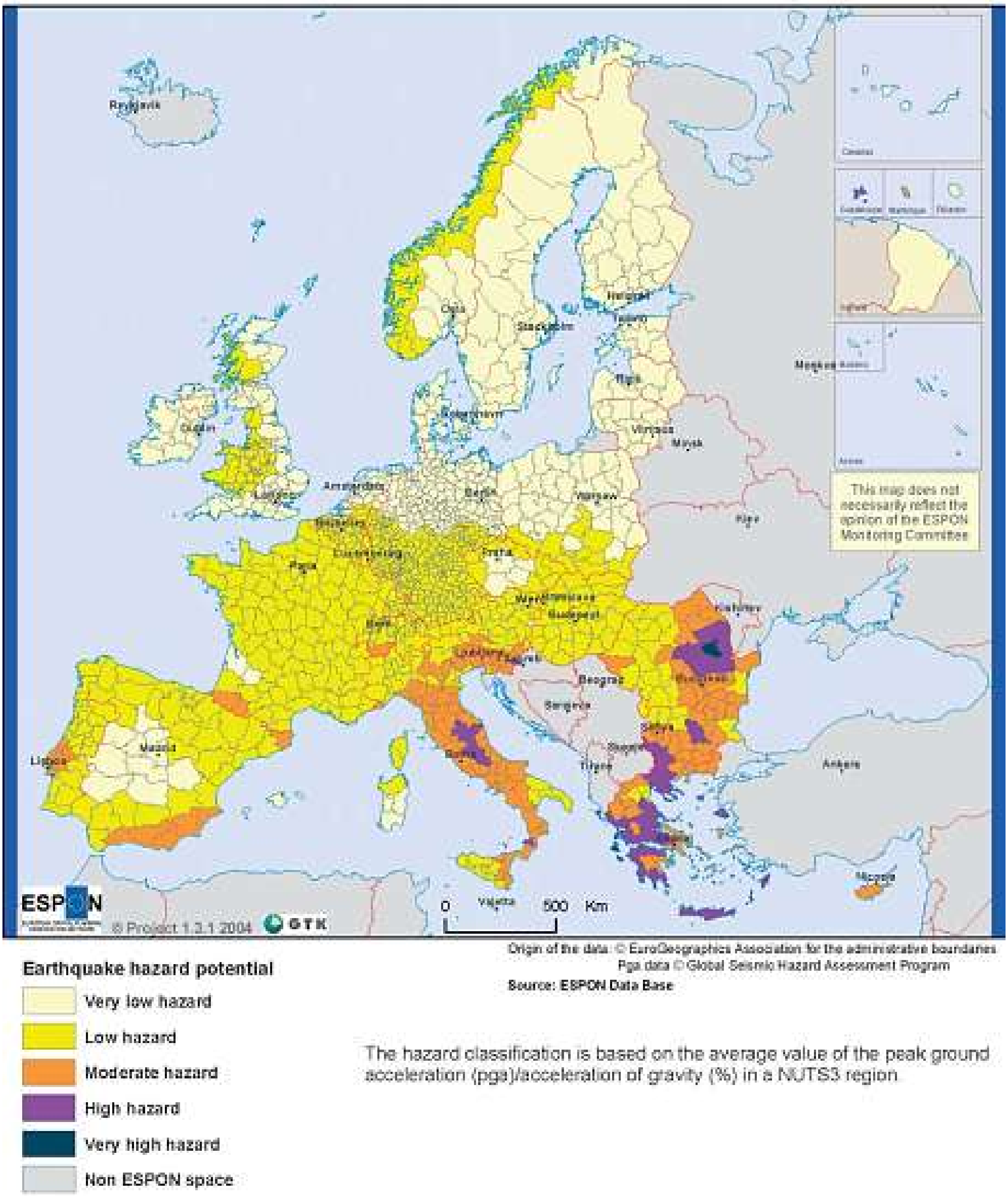
To create the hazard potential classification in five classes, the mean value of the grid points inside the NUTS 3 boundaries were calculated. This method will lower the effect of the peak values in the area. The classification of the GHASP project was turned to five classes by the ESPON Hazards project (Table 4.).

Table 4. Earthquake hazard classification.

Peak ground acceleration	
0–4% g	Very low hazard
4–14% g	Low hazard
14–24% g	Medium hazard
24–40% g	High hazard
> 40% g	Very high hazard

Map analysis

The highest earthquake hazard is concentrated in southeastern areas of Europe, such as Greece, Italy and Romania. Due to the theory of plate tectonics, it has become evident that most earthquakes occur along the margins of plates, where one plate comes into contact with another, thus developing shear stresses. There are, however, examples of significant earthquakes apparently not associated with plate boundaries. The earthquake activity zone affecting continental Europe is sometimes called the “Mediterranean and trans-Asiatic” zone. Earthquakes in this zone have foci aligned along mountain chains. These active zones have not changed significantly through human history (Radu & Purcaru 1964).



Map 3. Earthquake hazard.

1.4 Extreme temperatures

Hazard characterisation

Extreme temperatures are significantly higher or lower than the average temperature of a regional climate. Summers can be significantly hotter or colder than average, and winters can be colder or warmer than average. The strong climatic differentiation of the EU 27+2, area from the Mediterranean to sub-arctic climate, does not allow single extreme temperature figures for the entire continent. Extreme temperatures are mostly described as an excess of the average temperatures in a climate zone or a typical regional climate.

Fig. 4. Transport problems caused by extreme temperatures. Source: Michael Schmidt-Thomé 1983.

Extreme heat can lead to strong health impacts that mostly affect the oldest and the youngest of a population. Power plants might also have problems because cooling water taken from rivers, lakes or the sea may be too warm, thus the plants would have to run on lower energy output. This can lead to problems in power support, because production energy and households would consume more energy to run their own cooling systems. Finally, power cuts can have extreme impacts on the producing industry and thus on the economy of an entire country.

Extreme cold leads to a stronger use of heating systems, which can then lead to a shortage of energy and even power cuts. Extreme cold can also physically damage heating systems (cracking pipelines, tubes). In cases of severe shortage of heat, extreme cold can lead to serious health damages or fatalities.

Risk management

Hence extreme temperatures cannot be forecasted on a long-term basis and cannot be directly mitigated, they can only be managed by proper disaster plans that regulate the behaviour of authorities and emergency facilities in case of a heat or cold wave. For example, the use of energy can be controlled in case of low energy availability and emergency plans can regulate the use of hospitals, and the supply of needed goods.

Extreme temperatures hazard map

The extreme temperature map is based on data from the Swedish Meteorological and Hydrological Institute (SMHI) Rossby Centre's Regional Atmosphere-Ocean Model (RCAO). The data is in grid format (size approx. 50x50 km) and the time span covers 1961–1990. The four equally weighted factors are described in Table 5.

All four factors are classified on an ordinal scale with five classes based on the temperature distribution over Europe. The extreme temperature hazard indicator is based on the mean value of these four factors. The mean values of each NUTS 3 region are

Table 5. Four factors of the extreme temperature indicator.

Hot days	The 99th percentile of daily temperatures
Heat waves (7-day maximum temperature)	The 90th percentile of annual maximum 7 day average temperature
Cold days	The 1st percentile of daily temperature
Cold waves (7 day minimum temperature)	The 10th percentile of annual minimum 7 day average temperature

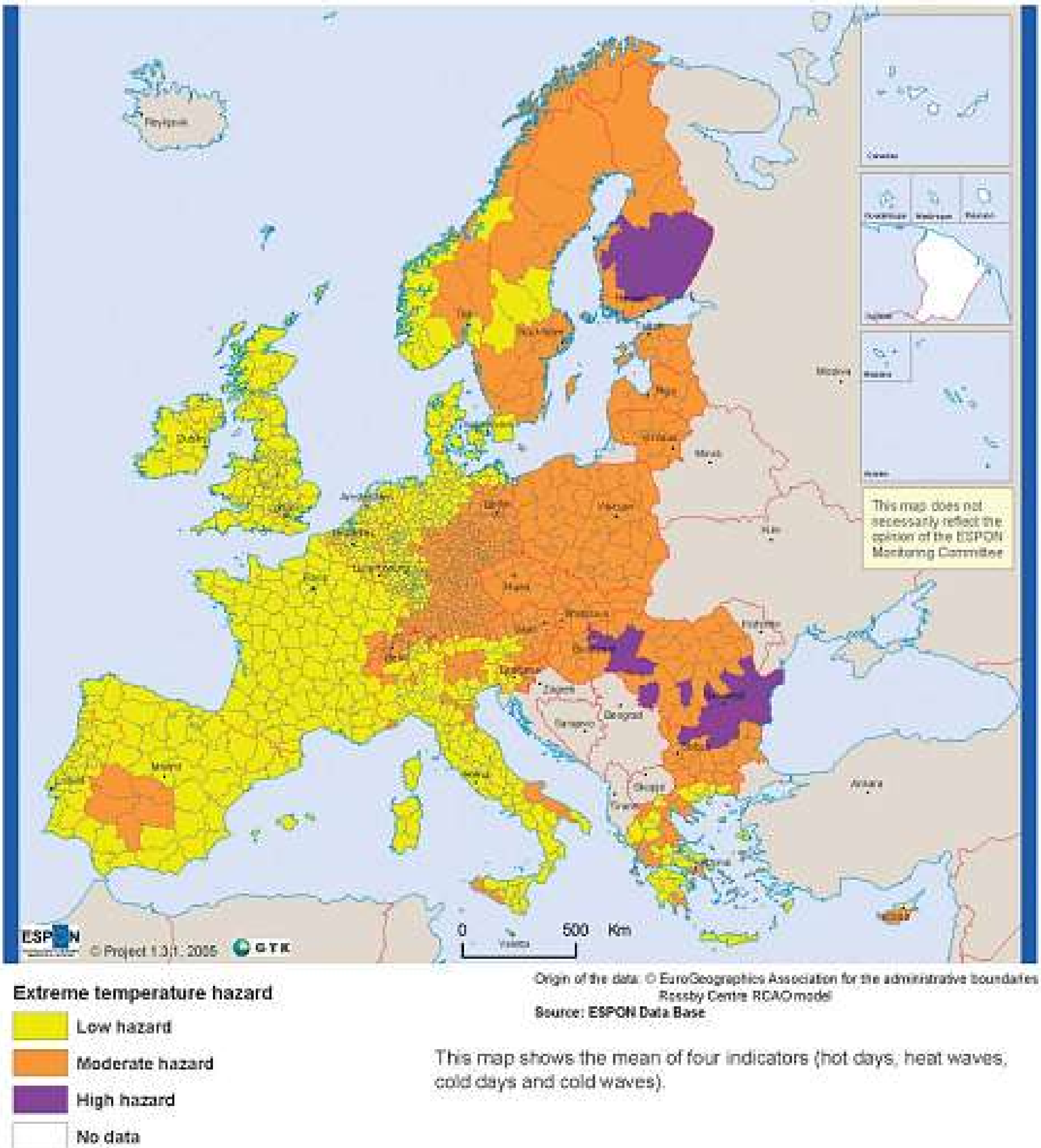
classified into three categories (Table 6.). The hazard values "very low hazard" and "very high hazard" are not represented in this scale, because there are no such exceptional areas in EU 27+2 where both, extreme coldness and extreme heat appear in the same area.

Table 6. Extreme temperature hazard classification.

Mean = 2-2.75	2 Low hazard
Mean = 2.75-3.25	3 Moderate hazard
Mean = 3.25-3.50	4 High hazard

Map analysis

The extreme temperatures index map of Europe shows a general trend of an increasing extreme temperature hazard from east to west. The reason for these trends is that the more continental the climate, the more extreme the temperature differences. More continental climates generally show stronger annual temperature amplitudes than marine influenced climates. The higher hazard in northern Europe is also based on the strong variation of solar radiation in summer and winter. This effect might grow in con-



Map 4. Extreme temperature hazard.

nection with climate change as northern Europe might show a higher hazard of extreme temperatures due to a quicker effect of climate change observed in the Arctic than so far presumed (Hassol 2004). Areas that are closer to the Arctic might respond quicker to climate change than areas located further way from it.

1.5 Floods

Fig. 5. Weißeritz river (flash) flood in Dresden in August 2002. Source: Frank Lehmann.

Hazard characterisation

Floods are here defined as high-water stages where water overflows its natural or artificial banks onto normally dry land, such as a river inundating its floodplain, occurring at more or less regular intervals. Floods are a as natural phenomena when the river runoff is so strong that the riverbed is too small to contain the water. Floods occur most often in Europe in springtime, when the winter snow and ice is melting. Strong floods happen irregularly, in so-called re-occurrence intervals of 10, 50 or 100 years. However, these intervals are only statistical averages, for example the Rhine/Mosel catchment areas were hit by 100-year return period floods at the end of 1993 and in the beginning of 1995. Heavy summer rainfalls can also lead to floods, as happened for example in 1997 in the Oder and 2002 in the Elbe basins. Floods have become an increasing problem for the built up environment since human beings have started to change, straighten and relocate river beds, and also by settling in low lying areas close to rivers, often in natural flood prone areas. Also, increased soil sealing leads to a higher flood hazard, as rainwater runs off directly into the streams and the water mass inflow to rivers is no longer delayed by natural soil retention.

Flash floods can contribute to river floods, or can be caused by river floods, if, for example, an embankment collapses. Flash floods can occur all over the European territory but are mostly bound to catchment areas and are thus integrated into the map of large river floods in Europe.

Risk management

The most important part of flood risk identification and management is the flood-prone area (extent) delineation. Flood-prone areas are those areas subject to inundation as a result of flooding with certain frequency. The determination of flood prone areas requires considerable correlation of historical data, accurate digital elevation data, discharge data and cross-sections that are located throughout the watershed (Lear J. et al.). In Europe, this complex kind of data is available only from certain case study areas. So far, flood prone area mapping in Europe does not follow a cohesive approach, because there are several approaches in different catchment areas or riverbeds.

Large river flood events recurrence map in Europe

This report presents the first aggregated large river flood map of Europe, based on the recurrence of floods in the time span of 1987–2002. The regional flood hazard for this 15-year period is displayed on NUTS3 level. Due to the unavailability of data to produce a flood map using on probability calculations, historical data were used to show the spatial patterns of the flood problem. The resulting large river flood map is mainly based on the "Global Active Archive of Large Flood Events", of the Dartmouth Flood Observatory. This observatory detects, maps, measures, and analyses extreme flood events worldwide using satellite remote sensing. The Global Active Archive of Large Flood Events does not yet completely cover the time period 1987–2002, because the delineated flood areas from the years 1989, 1990, 1991, 1995 and 1996 are still missing. Therefore, some of the missing floods were completed from other sources (Rhine Atlas, 2001 and Envisats online data sets).

The Dartmouth Flood Observatory digitised flood areas were changed to a relatively coarse raster size (25km x 25km) to avoid detailed interpretation. Representing this data on the NUTS 3 level therefore shows a generalized overview on the EU 27+2 territory. In this "Flood hazard recurrence" map, the average value of the registered large flood events was calculated for each NUTS 3 area.

The recorded floods do not show the magnitude of a single flood but the extent of a flooded area. Since the used data does not give any information on the depth of inundation, and this kind of data does not exist for the ESPON space, the flood reoccurrence map shows the amount of floods per NUTS 3 level regardless of its magnitude.

Table 7. Major river flood hazard classification.

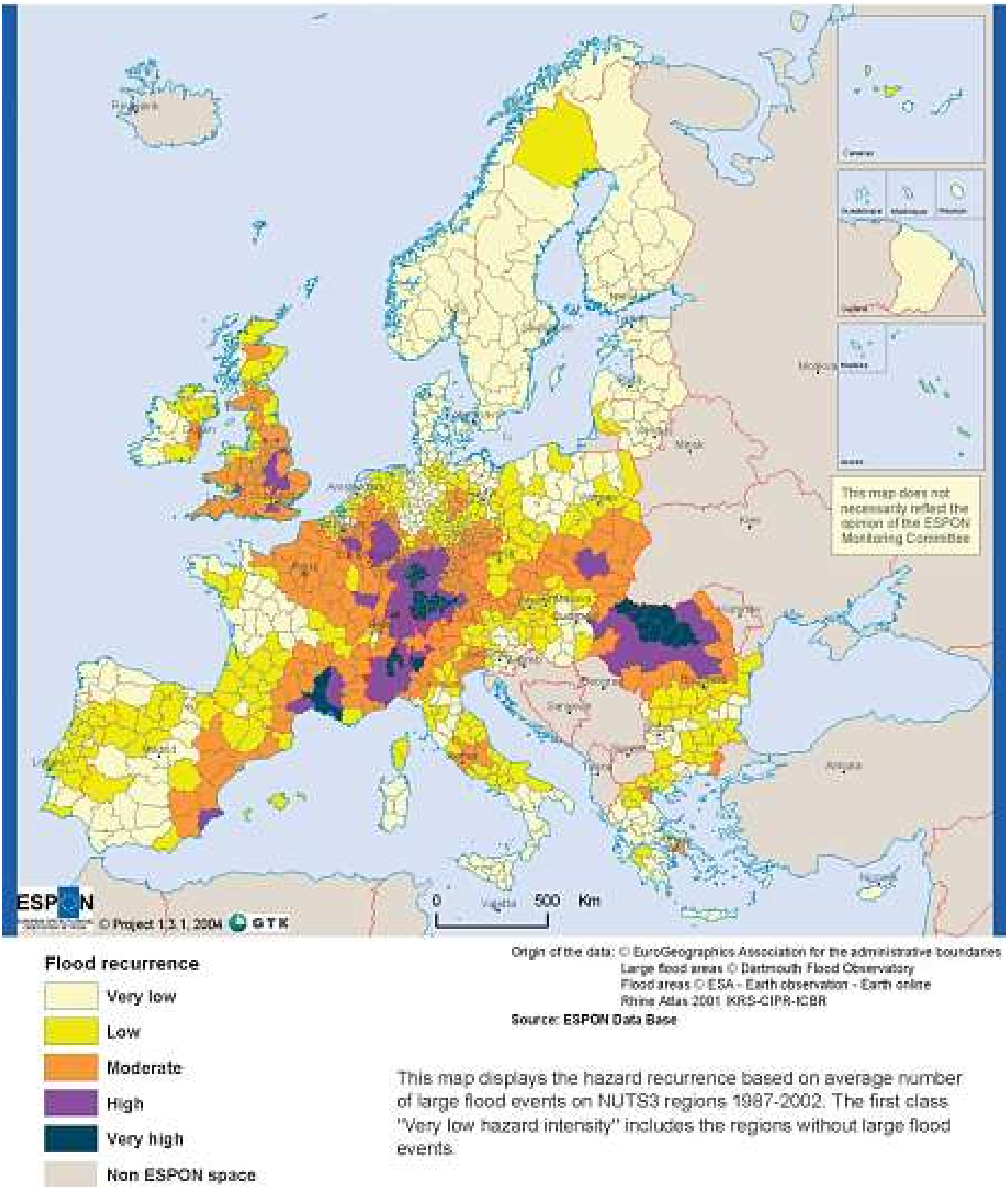
Number of observed floods per NUTS3 level	Hazard classes
0	1 Very low hazard
1*	2 Low hazard
>1 – <=2	3 Moderate hazard
>2 – <=3	4 High hazard
>3	5 Very high hazard

* This classification is synthetic and points out the recurrence of large flooding events in Europe, while the magnitude of single flood events is not taken into consideration.

Map analysis

The highest amount of large flood events between 1987 and 2002 are concentrated in northwestern Romania, southeastern France, central and southern Germany and eastern England. As explained above, the source data were obtained through satellite images and the mapped areas may not coincide perfectly with areas that have actually experienced floods. Also, the observation period is rather short to have actual statistical significance. Another problem with the data is the lack of flood magnitude information, as 100-year return period flood events cannot not be distinguished from the more frequent ones.

Even though this kind of map is actually not usable as a flood prone area map, because it displays past events and does not forecast possible future events, it gives a representative picture of the flood hazards on European scale. This was shown, for example, for the floods in southern France in 2004 and those in central and eastern Europe in 2005, as the flood hazard map depicts these areas.



Map 5. Large river flood hazard.

1.6 Forest fires

Fig. 6. Forest fire research in the Central Region of Portugal. Source: Jaana Jarva 2004.

Hazard characterisation

Forest fires (wild fires) can cause considerable damage in environmental terms, through the destruction of fauna and flora, and also causing human casualties. They also have serious economic implications on forestry, infrastructure and private property. Forest fires are natural phenomena (self ignition, lightning) that are very important for the natural living process of a forest. They lead to a natural cleaning process of forests, as excessive dead wood is burnt. However, most of the forest fires today are caused by human activities.

Risk management

A forest fire is a complex phenomenon that is difficult to model and manage. There are many factors that co-exist for the ignition of a forest fire. These include human factors (population density, road density), topographic variables (slope steepness and direction), meteorological variables (temperature, precipitation) and vegetation variables (land cover type, moisture content, availability of fuel). The major problem is that a large amount of forest fires are caused by human action, like arson, which is difficult to model or predict in any form. According to the Global Forest Fire Assessment 1990–2000 of the FAO (Goldammer & Mutch 2001), forest fires caused by human activities in the Mediterranean basin reach 90–95%, while natural causes represent only a small percentage of all fires (from one to five percent, depending on the country).

The spread of forest fires and the behaviour of fires are investigated in many EU research projects. These research activities help to foresee the development of a fire under certain meteorological conditions and according to topography. The knowledge achieved from this research has helped to limit the extent of fires and to protect human lives.

Until the end of 2002 the European Commission Regulation (EC) No 804/94 has given certain detailed rules for the application of Council Regulation (EEC) No 2158/92 as regards forest-fire information systems. The new Regulation (EC) No 2152/2003 (November 2003) also focuses on studying forest fires, incorporating the earlier regulations.

Forest fire map

There is extensive research on forest fire forecasting currently no forest fire potential maps are available on an EU scale. The forest fire hazard map developed by the ESPON Hazards project is a combination of vegetation zones (European Environment Agency 2003) and observed forest fires from 1997 to 2003 (ATSR World Fire Atlas).

The vegetation zones, which are regulated by climate and the relief, play a major role in the physical potential of forest fires. A combination of these two factors leads to a valuable overview on the forest fire hazard on European scale. Most fires have been observed in the Mediterranean vegetation zone, while gradually lessening towards the arctic and alpine vegetation zones. Accordingly, the European vegetation zones (EEA 2003) were categorised into five “forest fire potential” classes. The lowest class are alpine and arctic regions, the second class Atlantic, the third Boreal, the fourth Continental, Steppic and Pannonian, and the fifth highest Mediterranean.

The observed forest fires were also categorized into five classes, according to the amount of forest fires per 1000 km^2 within the years 1997 to 2003. The amount and density of observed forest fires (ATSR World Fire Atlas) give a good overview of the distribution of fires on a European level but the short observation period does not allow detailed conclusions on the actual hazard on a regional level. The main limitations of the database used are that only nighttime fires are detected and the repeat cycle of the satellite is three days. Fire temperature and extension are also not taken into account.

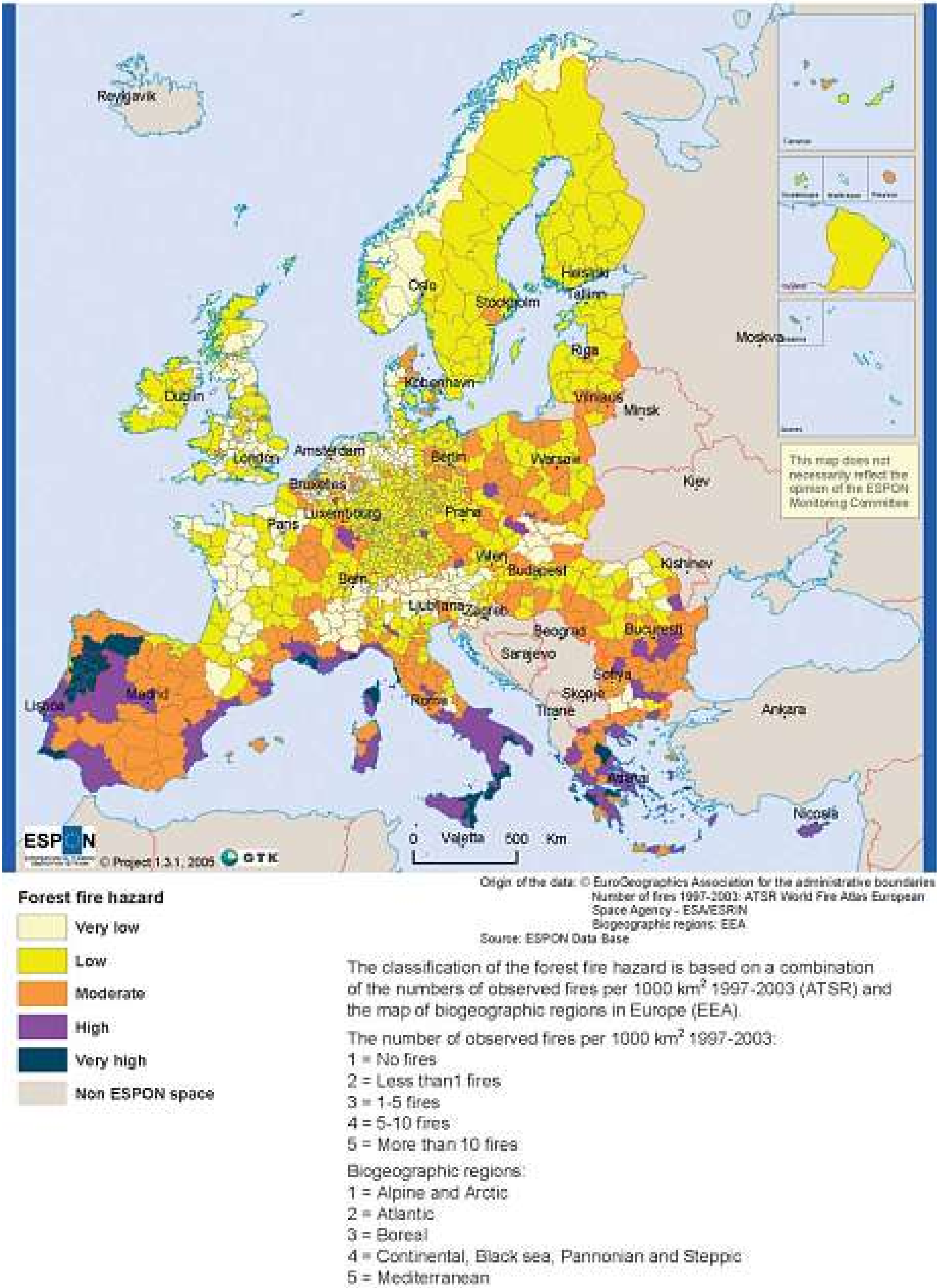
The forest fire hazard classification on NUTS 3 level is based on the sum of the vegetation zone class and the forest fire class. According to this classification, the highest forest fire hazard for alpine regions is medium (in case of a high density of forest fires but low vegetation class) and the lowest forest fire hazard in the Mediterranean vegetation zone is also medium (in case of a low density of forest fires but a high potential. Despite of the limitahous described abore). This straightforward classification scheme gives a representative picture of the forest fire hazard on European scale, also according to several interviewed forest fire experts.

Table 8. Forest fire hazard classification.

Observed forest fires per 1000 square kilometres	Hazard class	Biogeographic regions	Hazard class	**Resulting sums**	**Resulting forest fire hazard classes**
No forest fires	1	Alpine and Arctic	1	**2–3**	**1 Very low hazard**
1	2	Atlantic	2	**4–5**	**2 Low hazard**
2–5	3	Boreal	3	**6–7**	**3 Medium hazard**
6–10	4	Continental, Black Sea, Pannonian and Steppic	4	**8–9**	**4 High hazard**
>10	5	Mediterranean	5	**10**	**5 Very high hazard**

Map analysis

The forest fire hazard map shows that the areas with the highest potential for forest fires lie in the Mediterranean, partial areas of Romania and Bulgaria and in some hot spots in central Europe. The largest areas with the highest hazard lie in central-northern Portugal and in northwestern Spain, due to local slash and burn practices that are a dreadful combination with the high natural forest fire potential. The trend of increasing fire occurrences in southeastern European countries is a consequence of the changing rural and urban space due to the economic transition. Unprecedented numbers of catastrophic fires and areas affected by fire have been observed since 1991 (Goldammer 2002).



Map 6. Forest fire hazard.

1.7 Landslides

Fig. 7. Landslide in Crete. Source: Philipp Schmidt-Thomé 2003.

Hazards characterisation

The term landslide includes a wide range of mass movements, such as rock falls, deep failure of slopes, and shallow debris flows. Although gravity acting on a slope is the primary reason for a landslide, there are other contributing factors, such as erosion processes, water saturated soils after rainfalls and snowmelts, heavy loads deposited on slopes, for example by snowfall or from ashes of volcanic eruptions, and seismic activities. Human activities can cause landslides, because of artificial slope constructions (roads, stockpiling, mining) and deforestation. The term landslide comprises many geotechnical subterms that all have different causes and effects. Also, different European regions use varying terms for similar phenomena. The ESPON Hazards project uses the general term “landslide” to express the hazard of gravity forced mass movement of material on a slope that could lead to potential structural damages and accidents.

Risk management

In the case of landslides, it is most difficult or even impossible to assess return periods or probabilities of occurrence. Estimations for landslide probability due to local geological, morphological, meteorological and other conditions are possible for all areas sensitive to landslides. Although the physical cause of many landslides cannot be removed, local geologic investigations and good engineering practices, as well as effective enforcement of appropriate land-use management regulations can reduce landslide hazards. Landslides are local phenomena that should be managed by local studies.

Landslide hazard map

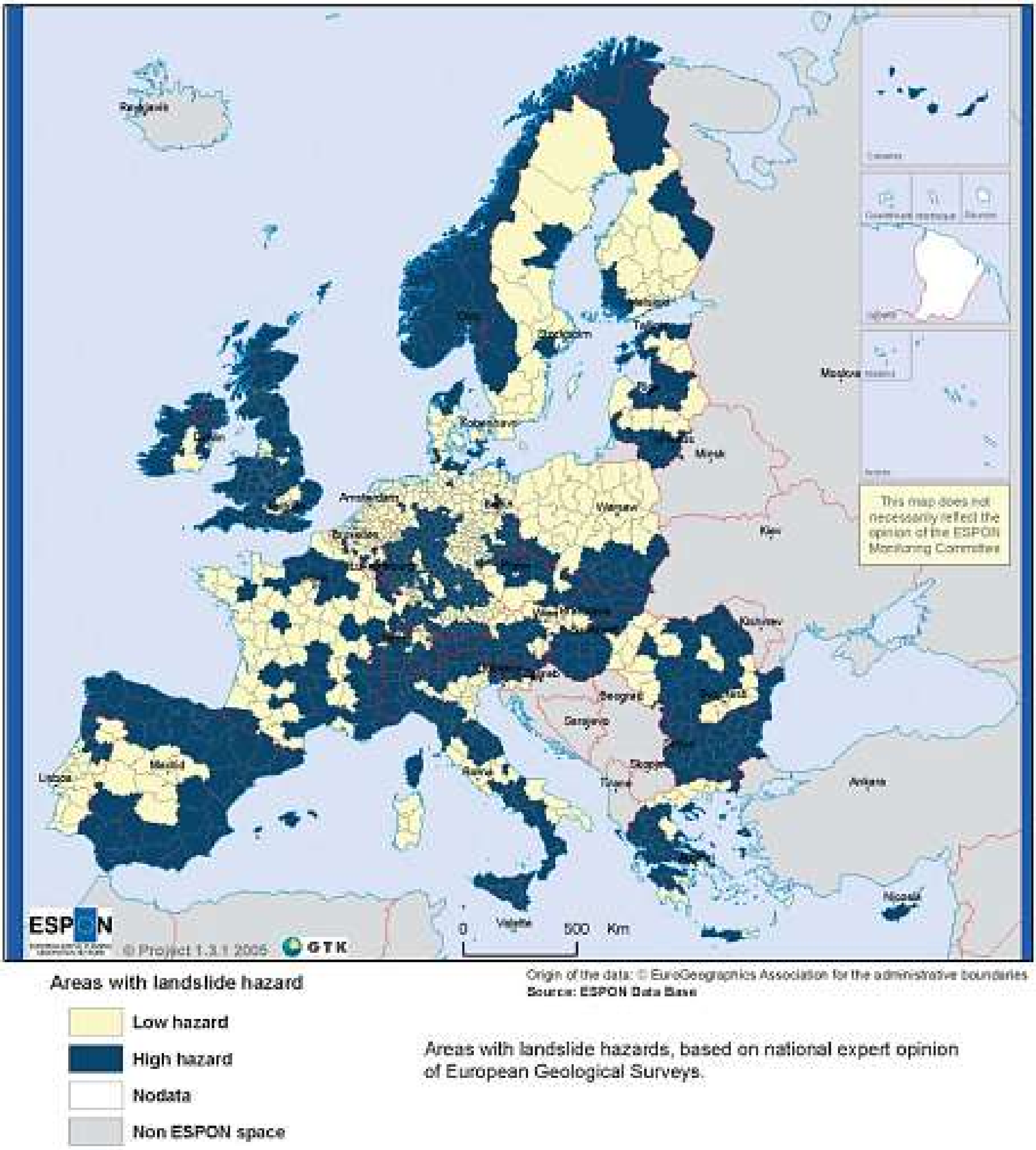
The NUTS 3 level is too coarse for pinpointing areas sensitive to landslides. To develop a first overview map on the problem of landslides in European regions, the ESPON Hazards project developed a questionnaire that was sent to geological surveys of Europe. Based on expert opinion, the geological surveys were asked to mark those NUTS 3 areas of their respective country or region that have the possibility of landslide hazards in general terms. To keep the comparability of simply displaying the landslide hazard, probability and risk factors were excluded. Some regions included so-called human induced landslide problems, for example, in open pit mines.

Table 9. Landslide hazard classification.

No or unknown landslide potential	1 Very low hazard
Landslide potential	5 Very high hazard

Map analysis

The landslide hazard in the European regions map gives an overview of the landslide hazard but does not assess in any detail in which parts of the regions landslides occur nor the causes of landslides (geology, relief, construction, etc.). A striking point in the map is the large extent of the landslide hazard in European regions, showing that even though the total amount of losses due to landslides in Europe is not economically very significant (Munich Re 2004), the hazard itself is rather widespread over the entire European territory.



Map 7. Landslide hazard.

1.8 Storm surges

Fig. 8. Flooding caused by a storm surge in downtown Helsinki, January 2005. Source: Philipp Schmidt-Thomé.

Hazard characterisation

Storm surge is seawater that is pushed toward the shore by the force of the winds of a strong storm. This rise in water level can cause severe flooding in coastal areas, particularly when the storm tide coincides with the normal high tides. In northern Europe, many coastal areas lie just above or even below the mean sea level and the danger from storm surges is very high. Storm surges can appear in may European areas, but due to the high winter storm probability, some parts of the North Sea and Baltic Sea shorelines are especially vulnerable to this hazard.

Risk management

The North Sea coast has experienced severe storm surges throughout human history, the largest recent devastating surges hit the Netherlands in 1953, killing 2100 people, and the German North Sea coast and Hamburg in 1962, killing over 300 people. Better coastal management and the erection of stronger sea walls have since protected the coastal areas from such catastrophes, even though the coast has been hit by stronger winds and higher water levels in 1973, 1981 and 1990 (strongest recorded storm surge so far) (Junge 2005). Nowadays, many of the North Sea territories have Integrated Coastal Zone Management (ICZM) plans that clearly define the land use in coastal zones, the coastal protection measurements and the hazard management facilities (Ministry of the Interior of Schleswig-Holstein, 2003).

Storm surge map

In the case of storm surges, coastal morphologies (lowlands versus cliff coasts) and coastal protection measurements (like sea walls) play an important role in the actual threat that surges pose to the coastal areas. The existing data sets do not yield enough information for such a classification on the entire EU

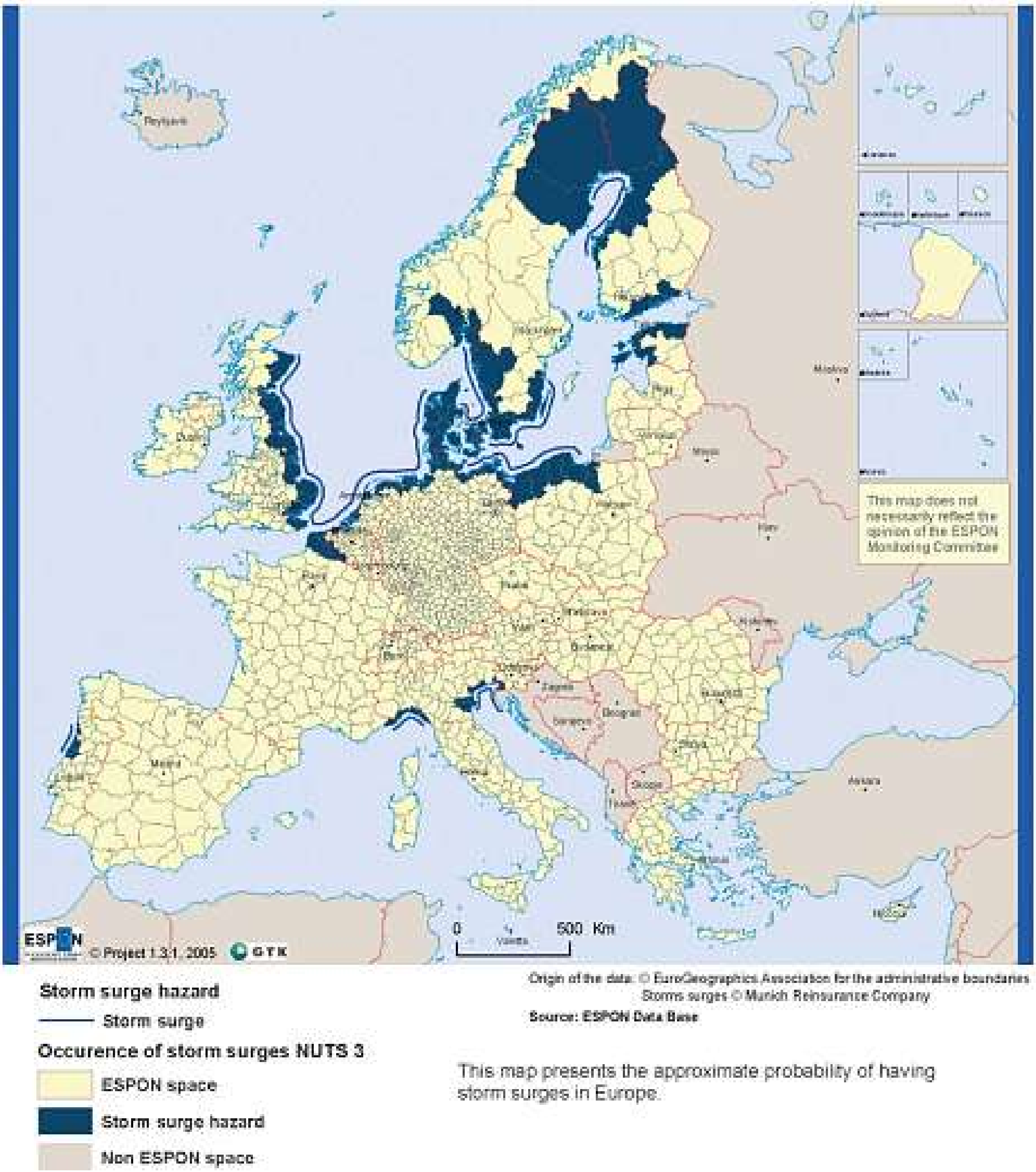
27+2 area. Therefore, storm surges are represented as a general hazard in areas where they might occur.

Table 10. Storm surge hazard classification.

No or very low storm surge probability	1 Very low hazard
Medium or high storm surge probability	5 Very high hazard

Map analysis

Storm surges are often closely linked to winter storms. Due to the influence of the coastal geology and morphology on the actual storm surge hazard, the areas with a high storm surge hazard are mostly located in the western, southern and eastern North Sea shores, as well as the western, northern and eastern Baltic Sea shores.



Map 8. Storm surge hazard.

1.9 Tsunamis

Fig. 9. Destruction of a tourist resort in Thailand by the 26.12.2004 tsunami. Source: Michael Schmidt-Thomé 2005.

Hazard characterisation

A tsunami is a series of waves generaled when a body of water is rapidly displaced on a massive scale. It is caused by earthquakes, large landslides, volcanic activities and meteorite impacts. The term derives from the Japanese expression for "large harbour wave". When these waves hit the shoreline they can cause severe damages, both because of their destructive energy and the extensive floods. An additional hazard is the retreating water when the tsunami floodwater runs back into the sea (Pacific Tsunami Warning Center).

The destructive force of a tsunami was observed in east and southeast Asia on December 26, 2004. According to information from the Deutsche Welle, the official death toll of this tsunami has reached 300 000. (DW-World 22.02.2005).

In Europe, tsunamis can mainly occur in the Mediterranean Sea with short travel times and thus very short early warning possibilities. The most devastating tsunamis in Europe occurred in Sicily (1693), Lisbon (1755), Calabria (1783), and Messina (1908), each killing more than 50 000 people. These are only examples, as there have been many more tsunamis throughout European history. One of the most recent tsunamis in Europe hit the Balearic Islands in 2003 after a submarine landslide caused by an earthquake in Algeria (Hébert 2003). The runups of this tsunami were rather small, up to 2 metres, causing no injuries. Nevertheless, this incident and the short estimated travel time of the tsunami (20–30min) shows that tsunamis are a potential hazard all over the Mediterranean, and also in areas not marked on the World Map of Natural Hazards (Munich Reinsurance Group 1998). Other tsunami prone areas are the distant EU territories, many of which are located on or close to tectonically active zones and volcanoes.

Risk management

Since it is impossible to forecast earthquakes, it is also virtually impossible to forecast tsunamis; it is only possible to outline potential impact areas. These potential impact areas are derived from geologically active zones that have seismic hazards. However, not every earthquake, volcanic eruption or landslide necessarily trigger tsunamis. The Pacific Tsunami Warning Center (PTWC) installed in Hawaii, records all earthquakes in the Pacific, issuing tsunami warnings in case of major earthquakes. Even though the technology involved in the PTWC is very sophisticated, this system has not recognised larger tsunamis that led to many casualties, for example in Nicaragua in 1992 (Pararas-Carayannis 2000) and Papua New Guinea in 1998 (The Tsunami Risks Project 2000). Also, 75% of all tsunami warnings issued by the PTWC were false warnings (Globalsecurity.org 2005).

The tsunami hazard map

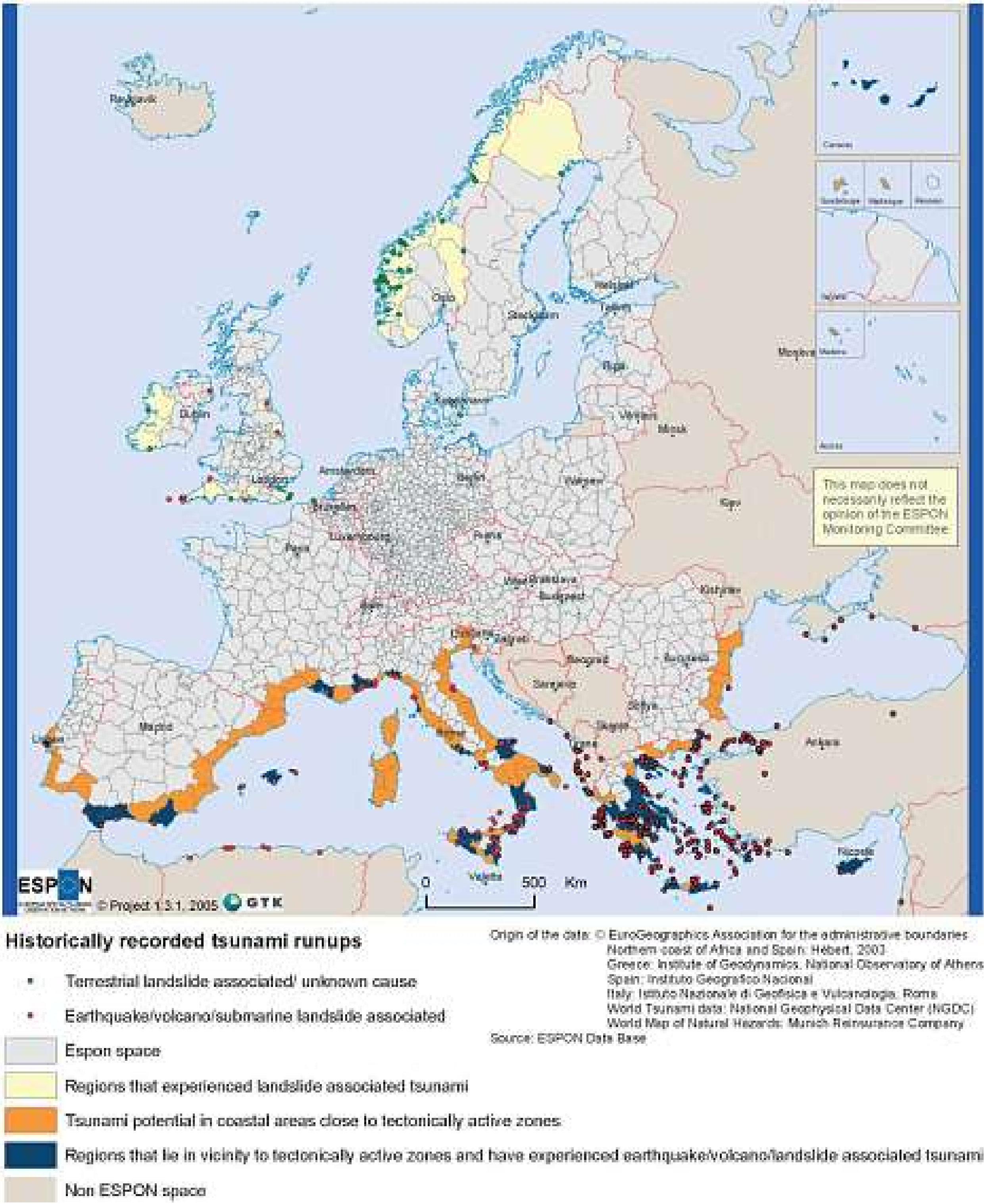
The tsunami hazard map was derived from several international data sources (see reference list in the map). Due to the high amount of recorded tsunami runup points and because of permanent tectonic activities, the Mediterranean is entirely marked as tsunami prone. In central and northern Europe, which is not as tectonically active as the Mediterranean, those NUTS 3 areas that experienced tsunami runups are marked as potential reoccurrence areas but are marked with a very low hazard class see Table 11).

Table 11. Classification of the tsunami hazard.

Areas that have experienced tsunamis that resulted mainly from gravitational landslides (terrestrial landslides)	1 Very low hazard
Areas in close vicinity to tectonically active zones	3 Medium hazard
Areas in close vicinity to tectonically active zones that have already experienced tsunami runups from earthquakes, volcanoes and/or resulting (submarine) landslides	5 Very high hazard

Map analysis

Tectonically induced tsunamis occur in Europe mainly in the Mediterranean and the Black Sea areas. There are several geological and historical records of tsunamis (National Geophysical Data Centre). The most endangered zones lie in close vicinity to the main volcanoes or along seismically active zones. Tsunamis caused by (submarine) landslides have mainly occurred in Norway, but also in some other areas in Europe. It is often difficult to distinguish if an earthquake caused a tsunami or if an earthquake triggered a (submarine) landslide that then caused a tsunami. In general, tsunamis are possible along all shorelines that lie in tectonically active zones and/or in areas where (submarine) landslides are possible. Even though no devastating tsunamis have occurred in Europe in the last 100 years, the potential hazard is still high.



Map 9. Tsunami hazard.

1.10 Volcanic eruptions

Fig. 10. Settlements on the slopes of a volcanic structure, Bañaderos/Gran Canaria. Source: Philipp Schmidt-Thomé 2006.

Hazard characterization

A volcanic eruption is here considered to be the arrival of solid products at the Earth's surface in the form of either the explosive ejection of fragmental material or the effusion of lava. This definition excludes energetic, but non ash-bearing steam eruptions. Major volcanic eruptions are destructive but their occurrence in Europe is quite low. Often, volcanic activity on convergent plate boundaries is explosive and on divergent plate boundaries effusive. The tectonic plate movements in the Mediterranean lead to explosive and effusive, as well as mixed types of eruptions.

Risk management

The damages that volcanic eruption causes are ash fall, lava flows, gases (sulphur oxides and nitrous oxide), hot ash clouds, lahars and volcanic earthquakes. Volcanic eruptions can also cause tsunamis and climate change (the ash that is thrown out in large eruptions may reach into the Earth's upper atmosphere blocking out the sun's rays and cooling the earth's atmosphere). Ash fall and tsunamis are capable of causing damage over a relatively large area, while other effects usually only threaten areas that are close to the volcano.

Volcano hazard map

The volcano hazard map is based on all volcanoes with known eruption dates in Europe within the last 10 000 years that are marked on the Volcanic Eruption Map of the Munich Reinsurarance Company (2000), compiled by the Global Smithsonian Institute. The hazard intensity classification is derived from Munich Reinsurance Company's classes.

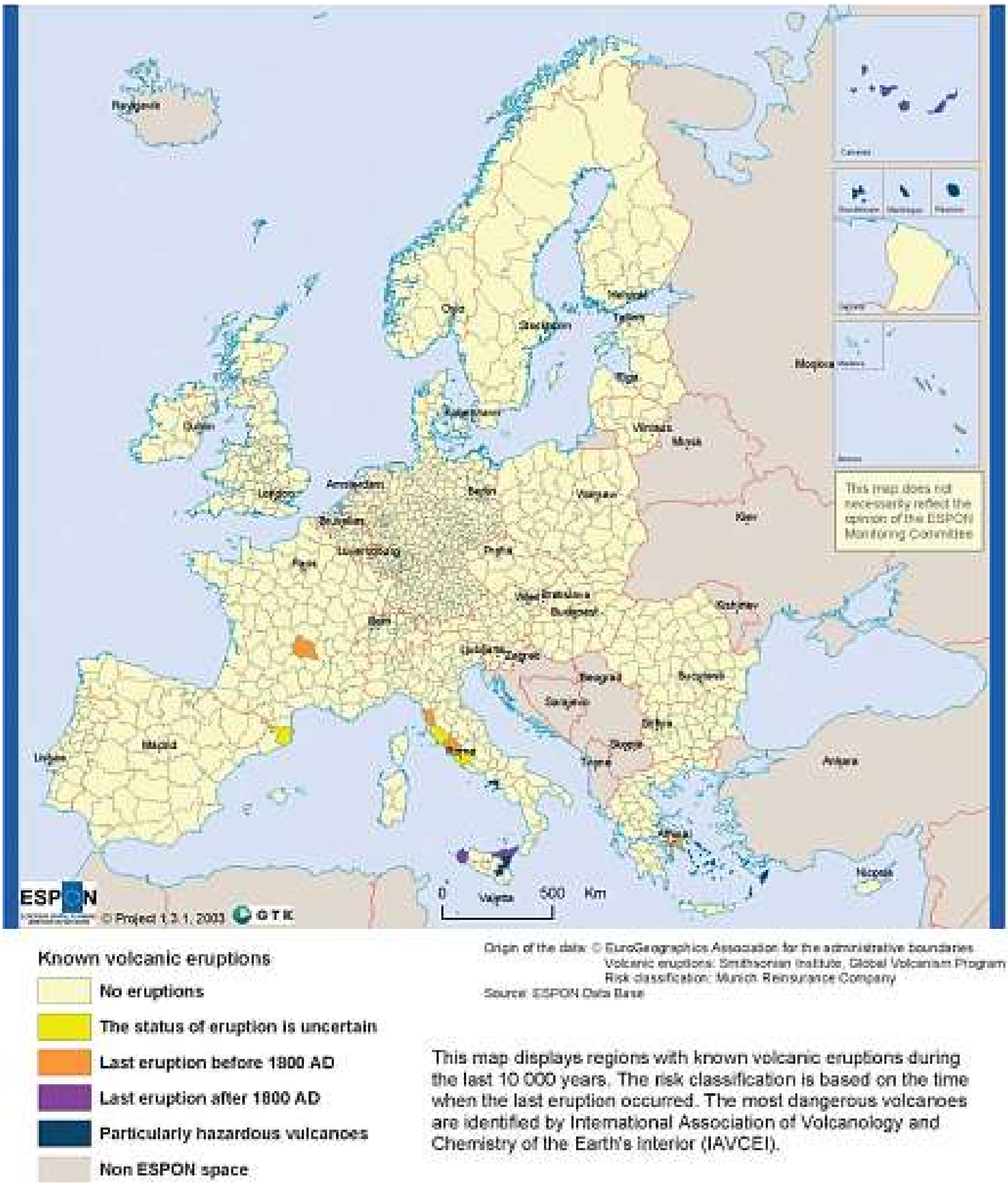
Table 12. Classification of the volcano hazard.

No eruptions	1 Very low hazard
The status of Holocene eruption is uncertain or Holocene activity is only hydrothermal	2 Low hazard
Last eruption before 1800 AD	3 Medium hazard
Last eruption after 1800 AD	4 High hazard
Volcanoes that are identified as being particularly dangerous by the International Association of Volcanology and Chemistry of the Earth's Interior (IAVCEI).	5 Very high hazard

The original data on volcanic eruptions is in point format. The number of eruptions in each NUTS 3 area has been investigated and the hazard intensity value has been calculated for an entire NUTS 3 area. The largest intensity value determines the hazard intensity value of the studied NUTS 3 area.

Map analysis

The highest volcanic eruption hazard is concentrated in southern Europe, for example in Italy, Greece and in the overseas territories. It must be considered that several Greek islands are clustered into NUTS 3 levels, thus every island is not its own NUTS 3 area. Therefore, the volcanic hazard is also displayed on islands that are not volcanic. In western Germany, the West Eifel volcanic field in the Rhineland district was active at the end of the Pleistocene and beginning of the Holocene. In central France, the Massif Central has been an active volcanic field in the beginning of the Holocene. In Spain, the Quaternary Olot volcanic field has been active 11 500±1100 years BP (Global Smithsonian Program).



Map 10. Volcanic eruption hazard.

1.11 Winter and tropical storms

Fig. 11. Effects of a winter storm and a storm surge in the Pärnu Bay/Estonia. Source: Philipp Schmidt-Thomé 2005.

Hazard characterisation

According to the Munich Reinsurance Company, storms are the highest reason for economic losses by natural hazards worldwide. Most of these storms occur in tropical and subtropical regions, such as tropical cyclones. Tropical cyclones occur only in European overseas territories, while tornadoes also occur locally in Europe, but these are seldom and difficult to predict. The most relevant storms for Europe are the so-called regional storms, like winter storms. These regional storms are also the highest cause for economic and insured losses in Europe. (Munich Re 2004)

Winter storms are the result of differences in temperature between the polar air masses and the air in the middle latitudes in autumn and winter. These extratropical cyclones generally have less destructive power than tropical cyclones or tornadoes, but they are able to produce damaging winds over a wide area.

Winter storms can have such associated effects as storm surges (result of prolonged onshore winds), floods, avalanches, landslides, high seas/waves (depending on the duration and intensity of a storm) and coastal erosion (wave action and suction on the shoreline), as well as snow pressure (heavy snowfalls).

Risk management

Winter storms are climate related hazards that are quite difficult to predict in advance. Their probability of occurrence is the highest in northern Europe, near the coastline. The occurrence as well as the magnitude of winter storms gets lower inland. The damages caused on buildings by winter storms are usually dominated by damage to roofs, windows and facades. The damages to nature, like felling of trees due to strong wind or heavy snowfalls, can also be massive. Falling trees can damage infrastructure like roads and power lines. Reducing the occurrence of winter storms is not possible, but it is possible to reduce the extent of damages caused by storms to a certain degree by proper maintenance of assets.

Winter and Tropical Storm map

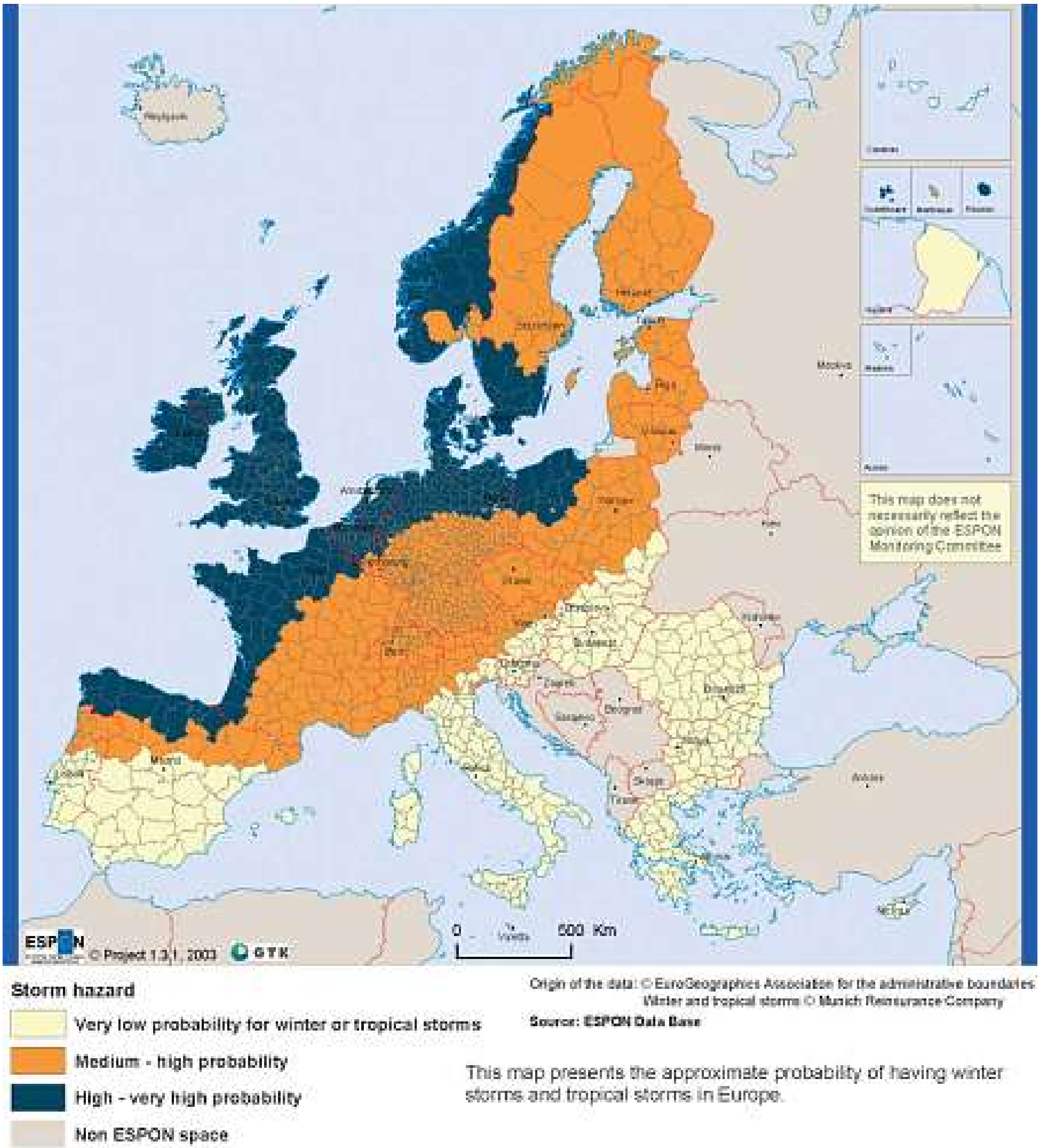
The winter storm and storm surge data are available from the World of Natural Hazards CD-Rom (Munich Reinsurance Company, 2000). The storm hazard is represented according to the probability of occurrence.

Table 13. Storm and storm surge classes.

No or very seldom winter (tropical) storm probability	1 very low hazard
Medium to high winter (tropical) storm probability	3 medium hazard
High to very high winter (tropical) storm probability	5 Very high hazard

Map analysis

The winter and tropical storm hazard map shows that the areas in Europe that are more exposed to the northern Atlantic experience the highest threat of winter storms and storm surges. Tropical storms occur only in the overseas territories. The winter storm and storm surge hazard gradually lessens towards southeast Europe as the climate changes from Atlantic influenced towards more continental.



Map 11. Winter and tropical storm hazard.

2 TECHNOLOGICAL HAZARDS

Most technological hazards focus on very small areas of emission (like chemical production plants, oil pipelines), while other technological hazards have a great perimeter of influence and can thus affect a relatively larger part of Europe. It is very difficult and in many cases impossible to exactly define threatened areas because of specific accident parameters, such as like the time of the day of an accident, and influence of weather. Due to its relatively densely populated area, the whole European territory is threatened by accidents (e.g. major accident hazards).

2.1 Air traffic accidents

Fig. 12. Aircraft that ran short of the runway and stopped just before hitting a motorway in Medellín/Colombia, 1985. Source: Michael Schmidt-Thomé.

Hazard characterisation

The hazards of airplane accidents in airport entry lines are part of planning schemes in many regional plans in Europe. Nevertheless, the specially protected areas in airport entry lines are only several hundreds of meters to a few kilometres in the extensions of runways, covering the very early take off and/or final landing approach phases of airplanes. These corridors are mainly designed because of noise protection and airplane security but they do not necessarily always take airplane crash statistics into consideration. To determine the real risk of airplane crashes in entry lines to airports or close to airports, the ESPON Hazards project carried out a detailed study of worldwide civil airplane crash statistics since 1970 (online aviation accident database).

Airline safety has generally improved since the end of the 1960’s, and since then accidents have decreased from over 300 in the 1970’s to approximately 250 in the 1980’s and 1990’s. The maximum number of accidents was found in 1970, with a total of 38 planes. Since the late 1990's, the amount of plane crashes stabilized to approximately 22 per year (Aviation accident database, A-Z World Airports Online 2005) (see Schmidt-Thomé 2005, Annex 3).

The results of the study reveal that the most dangerous flight phases are those of approach, landing or take off. Eighty percent of all crashes that occur during landing, final approach or take off occur within approximately 5km of airports.

The risk of military airplane accidents was not taken into account in this study, as there is no reliable information on military aircraft safety and the amount of flights per military air base in the EU 27+2 area.

Risk management

The risk of airplane accidents can be ensured by rigid safety standards on the technological and maintenance standards of airplanes, standards on the air traffic guidance systems and safety procedures before take off. The European Airline Safety Agency (EASA) ensures the highest possible safety standards for aviation in the European Union.

Hazard map on air traffic accidents

The air traffic hazard is based on the calculated main risk radius of 5km around airports. Since a 5km radius around airports (highest air traffic accident hazard) is difficult to display on European scaled maps, the map below displays all commercial airports in EU 27+2 and categorizes them into five classes according to the total annual volume of passengers in 2003. The hazard itself is thus based on the amount of passengers per year Data were selected from the European civil commercial airports. Figures for passenger traffic are mostly from 2003, in some cases older data sets between 1996 and 2002 were used.

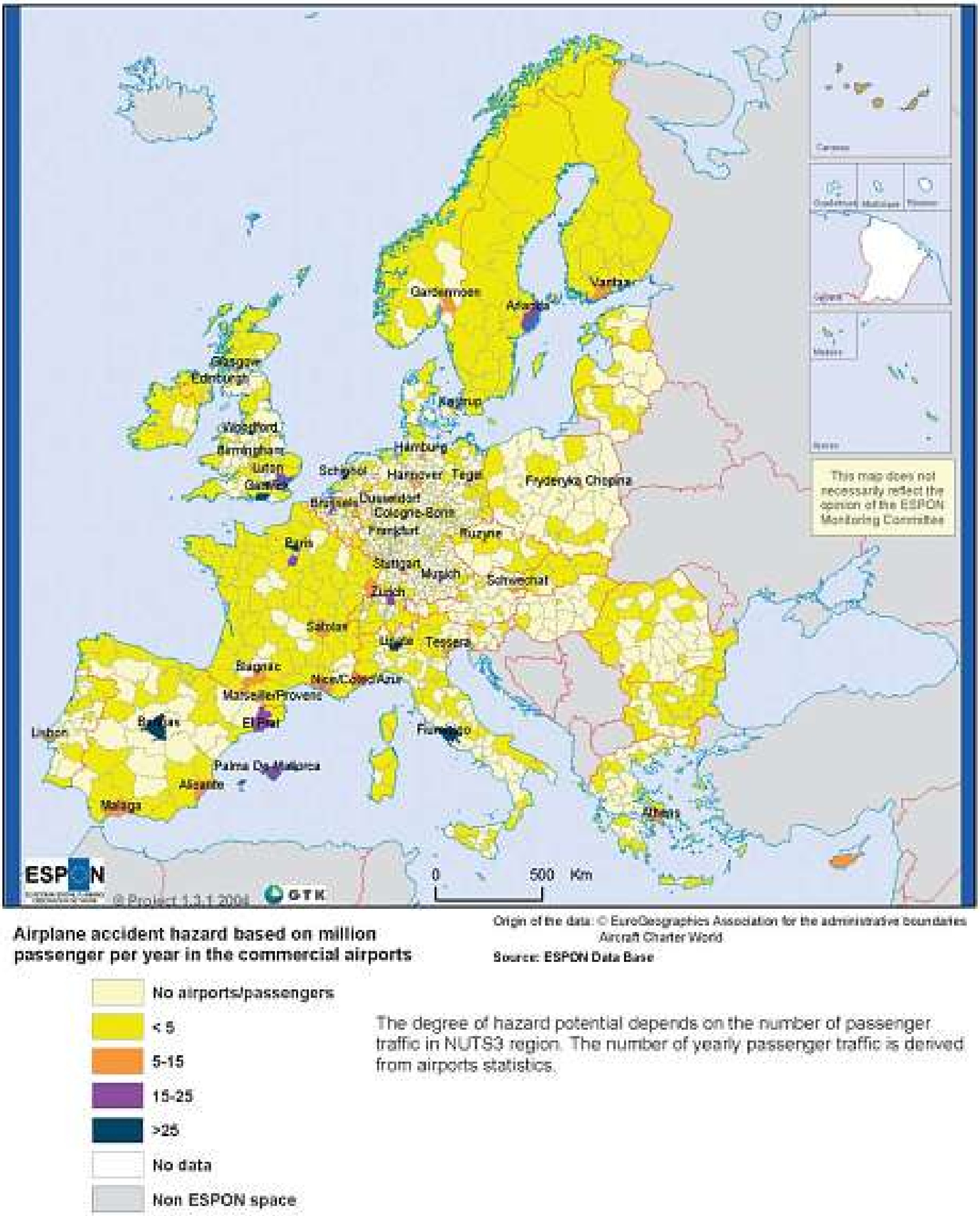
Other categories that could influence the hazard including safety standards, morphology, night flights, proximity to other airports were not taken into account. Based on these five classes, the hazard of airplane crashes on NUTS 3 level is the total sum of passengers.

Table 14. Classification of air traffic accident hazard per NUTS 3 level.

No airports	1=Very low
<5 millions passenger/a	2=Low
5–15 millions passenger/a	3=Medium
15–25 millions passenger/a	4=High
>25 millions passenger/a	5=Very high

Map analysis

The hazard map for air traffic accidents shows that the highest hazards are located around the major air traffic hubs. Northern European countries have an elevated hazard because they have a relatively higher density of civil airports than average, while eastern and southern European countries have a less dense airport structure.



Map 12. Air traffic hazard.

2.2 Major accident hazards (chemical plants)

Fig. 13. Chemical production plant in a residential area in Trieste/Italy. Source: Philipp Schmidt-Thomé 2005.

Hazard characterisation

The hazard type "major accident hazard" represents a wide range of different hazards. The most important similarity of these hazards consists in their origin as an emission from an industrial facility, like specific harmful substances being distributed out of a production area. The most threatened areas are the industrial facility and its employees itself. In addition, the area around the facility is threatened by emissions from the facility to the wider area. The possible impact of a major accident is nearly impossible to forecast, as it depends on the type of accident, the physico-chemical components, the transporting media (air/water), the current weather conditions, the speed of recognition and reaction. Also, the timing of an accident may largely influence the hazard, for example, the season (vacation time) weekday or weekend as well as the time (amount of traffic on the street, school children in schoolyards).

Risk Management

Within the European Union, the Council Directive 96/82/EC (SEVESO II) aims at the prevention of major accidents involving dangerous substances and the limitation of their consequences. The provisions contained within the directive were developed following a fundamental review of the implementation of the Council Directive 82/501/EEC (SEVESO I). In particular, plant management was identified as the major area where new provisions seemed necessary on the basis of an analysis of major accidents reported to the EU Commission since the implementation of SEVESO I. Failures of the management system were shown to have contributed to the cause of over 85% of the accidents reported. Against this background, requirements for management policies and systems are contained in the SEVESO II Directive. The directive sets out basic principles and requirements for policies and management systems, suitable for the prevention, control and mitigation of major accident hazards.

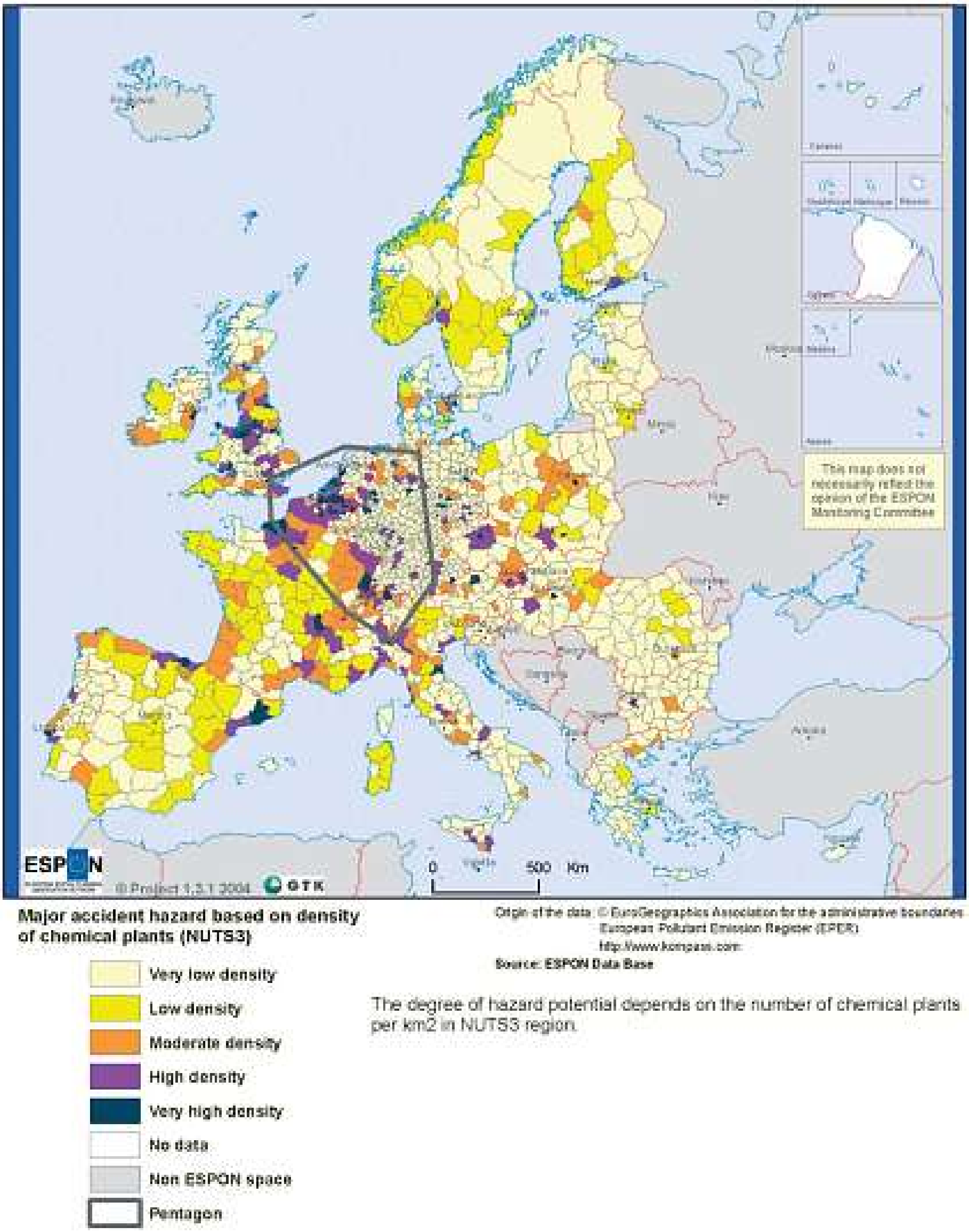
Example map on major accident hazards, chemical production plants

The example map on major accident hazards is synthetic, as it displays the number of chemical production plants per km^2 per NUTS 3 level, regardless of the substances handled, the size of the plant or the particular safety record of a plant. EU-wide information on other sources of major accidents hazards exists but is classified. The chemical plants hazard potential in NUTS 3 regions is based on the density of chemical plants as classified into five categories (Table 15).

The map focuses on chemical production plants as, among the categories of The European Pollutant Emission Register (EPER) database, these pose the highest theoretical risk of a major accident hazard. Data from EU 27+2 countries that are not yet available from the EPER database were collected from the KOMPASS database. The hazard is classified into five classes, according to the amount of chemical production plants per km^2 per NUTS 3 level.

Table 15. Classification of chemical plant hazard.

Share of chemical plants/km^2/NUTS 3 level	Density (hazard) class
[Share]=0	1=Very low
[Share]=0,000001-0,000318	2=Low
[Share]=0,000318-0,000830	3=Moderate
[Share]=0,000831-0,002535	4=High
[Share]=0,002526-0,066781	5=Very high



Map 13. Chemical production plant hazard (as an example of major accident hazards).

Map analysis

The example map of major accident hazards, the chemical production plants, shows that there is a strong clustering of this hazard in the so-called "Pentagon Area" (marked in map 13). As chemical plants are rather specialised sections of industrial productions, large areas of Europe, especially in the north and the east do not have any hazard from these plants. Most European areas have just a minor hazard and few areas in or adjacent to the "Pentagon Area" experience a medium hazard.

2.3 Nuclear power plants

Fig. 14 The Ignalina nuclear power plant, the same reactor type as the one in Chernobyl. Source: Philipp Schmidt-Thomé 2003.

Hazard characterization

The technological hazard related to nuclear power plants (NPPs) is special in many respects and needs to be treated accordingly. The consequences of a large-scale nuclear accident have a big spatial extent, as nearly all of Europe would be exposed to possible nuclear fallout. The theoretical frequency of occurrence (probability) of such an accident is extremely small, less than once in two million years (Fortum 1999). As a result, a simple calculation of averaged annualized losses caused by even a major nuclear power plant accident would result in negligible hazard intensity estimates throughout Europe. However, NPPs have to be taken into account in spatial planning considering that the time frame of planning is completely different from such million-year projections and keeping in mind the Chernobyl accident in Ukraine in 1986.

The Chernobyl accident was detectable in practically every country of the northern hemisphere. The largest particles, primarily fuel particles, were deposited within 100 km of the reactor. Small particles were carried by wind over large distances and their deposition depended on local rainfall. Meteorological conditions varied frequently during the 10 days of the accident, causing significant variation in the dispersion of contamination. The most highly contaminated area was the 30 km zone around the reactor where ground deposits exceeded 1500 kBq/m^2. The far zone of contamination ranges from 100 to 2000 km around the reactor. There, local rainfall produced three spots of especially high contamination. Areas outside the former Soviet Union were affected as the radioactive plume moved across Europe. After the accident, the wind carried the radioactive cloud first northwest over Fennoscandia, the Netherlands, Belgium, and the United Kingdom. Afterwards, the plume moved south and over much of central Europe, the northern Mediterranean area and the Balkans. Consequently, most countries in Europe received some deposition of radionuclides. (OECD NEA 2002)

Risk management

The most important risk management aspect for nuclear power plants is the reduction of the probability of occurrence of hazardous events in the nuclear facilities themselves. Indeed, the nature of nuclear power and the great damage potential has lead to the adoption of extensive, independent, multi-layered safety practices at the installations. In addition to the safety procedures at nuclear facilities, risk management is achieved by mitigating the effects of possible radioactivity releases from NPPs. Besides spatial planning responses, nuclear emergency plans have been developed at different administrative levels ranging from individual power plants and municipalities to national plans.

Nuclear power plants hazard map

Due to the overregional nature of the hazard, nuclear power plants of the non-ESPON space are included. Since the Chernobyl accident is the only example of an exploding nuclear power plant in human history, the presented risk assessment for Europe's power plants is developed according to the extent of radioactive contamination that resulted from this accident in 1986. The areas around nuclear power plants are classified according to those areas most affected into zones 1 (30km radius) and 2 (300km radius), that is the areas that have to be evacuated and those of mandatory resettlement, according to the International Communications Platform on the Long term Consequences of the Chernobyl Disaster (Chernobyl.info). Zone I covers all areas in a 30km distance of the Chernobyl nuclear power plant. All territories belonging to Zone II are within an approximate distance of 300km from the nuclear power plant. These areas were directly affected by the explosion, without influence of local wind patterns during the accident. All NUTS 3 levels falling into this radius are marked as "directly" and "indirectly" affected areas.

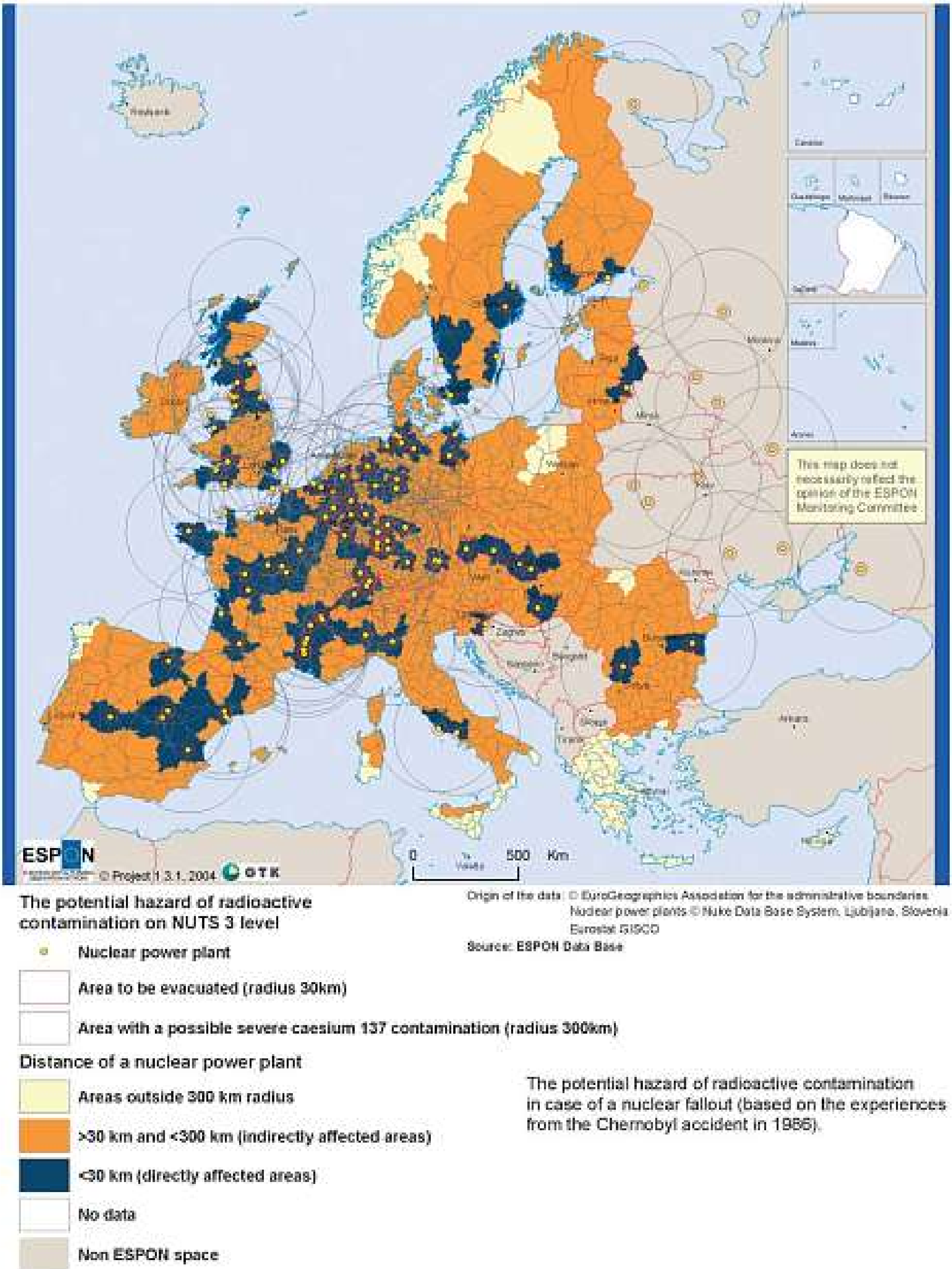
Table 16. Nuclear power plant hazard classes.

Regions that do not intersect the 300km radius	1 Very low hazard
Regions that intersect the 300km radius	3 Medium hazard
Regions that intersect the 30km radius	5 Very high hazard

Map analysis

The map is a theoretical, synthetic approach because accidents in nuclear power plants have a very low probability (see above). It is doubtful that the contamination, in case of an accident, would exactly follow the same patterns as in 1986. Nevertheless, the Chernobyl accident is the only major accident so far and the map shows its potential extent on a European level. An inclusion of major wind patterns in Europe is not feasible in this theoretical approach. The "indirectly affected areas" 300km zone chosen is the extent of major contamination around Chernobyl without taking atmospheric conditions into account.

An analysis of the map shows that there are only few areas in the marginal extremes of Europe that are not in the range of a theoretical "indirectly affected area" in case accidents similar to the Chernobyl incident occurred. Many countries that do not have any power plants are also in the potentially affected zones. The map displays the high amount of nuclear power plants in Europe with a strong agglomeration in the "Pentagon Area".



Map 14. Nuclear power plant hazard.

2.4 Oil processing, transport and storage

Fig. 15. Oil tanker in the Strait of Gibraltar. Source: Philipp Schmidt-Thomé 2005.

Hazard characterisation

All activities in oil production, processing, transport and storage pose a risk to contaminate contaminating the environment. Large tanker accident oil spills are the most catastrophic single pollution events, but the environment is constantly threatened by smaller accidents and general dispersion of oil. Offshore activities and refineries are an important source of oil pollution for the North Sea, but are of less significance for the Baltic and Mediterranean Seas, where offshore activity is much lower. Much of the Black Sea is severely polluted with oil, especially near ports and river mouths, mainly due to heavy traffic, as well as de-ballasting and bilge discharges (ITOPF 2005).

Oil processing plants, storage facilities and pipelines pose a permanent hazard because of the large amount of oil in a single spot. Data series from 1974–2004 suggest that discharges from offshore activities and refineries account for over 50% of the total incidence of oil spills (ITOPF 2005). A more detailed overview of different causes for oil spills is shown in the Table 17.

Table 17. Incidence of spills by cause 1974-2004. Source: ITOPF 2005.

	< 7 tonnes	7–700 tonnes	> 700 tonnes	Total
OPERATIONS				
Loading/discharging	2817	327	30	3174
Bunkering	548	26	0	574
Other operations	1177	55	1	1233
ACCIDENTS				
Collisions	167	283	95	545
Groundings	232	214	117	563
Hull failures	573	88	43	704
Fires & explosions	85	14	30	129
Other/Unknown	2176	144	24	2344
TOTAL	7775	1151	340	9266

Risk Management

Most of the oil spills result from routine operations such as loading, discharging and bunkering, activities that mostly take place in ports or at oil terminals. Thus, there is a specific increased risk for those locations. The majority of these operational spills are small, with some 92% involving quantities of less than seven tonnes (ITOPF 2005). Suitable strategies against large tanker accidents comprise double hull tankers, pilots on board, emergency anchor places, surveillance of shipping routes and strict maintenance regulations.

Oil processing, transport and storage hazard map

The overview map of oil production, processing, storage and transportation displays the main European maritime oil terminals, refineries, storage tanks and pipelines (CONCAWE 2002, World Port Index 2000). The hazard map on oil transportation, storage and processing is produced on NUTS 3 level. Therefore, oil platforms and shipping routes are no eligible sources of information. Currently, there is no information available on exact shipping routes and amounts or types of transported oil.

The hazard map assumes that the larger an oil terminal the higher the hazard, due to the higher amount of transported and handled oil. The same principle accounts for refineries and pipelines. The hazard map categorizes the NUTS 3 levels into classes according to the amount of oil terminals, pipelines and refineries. The risk of terrestrial oil pollution by means of transportation other than pipelines (like roads) cannot be displayed because it is ubiquitous among the dense European infrastructure (spatial filter for hazards, Fleischhauer 2006, *this volume*) and is therefore included in the lowest class. The resulting hazard is determined by the aggregation of one or more attributes per NUTS 3 level.

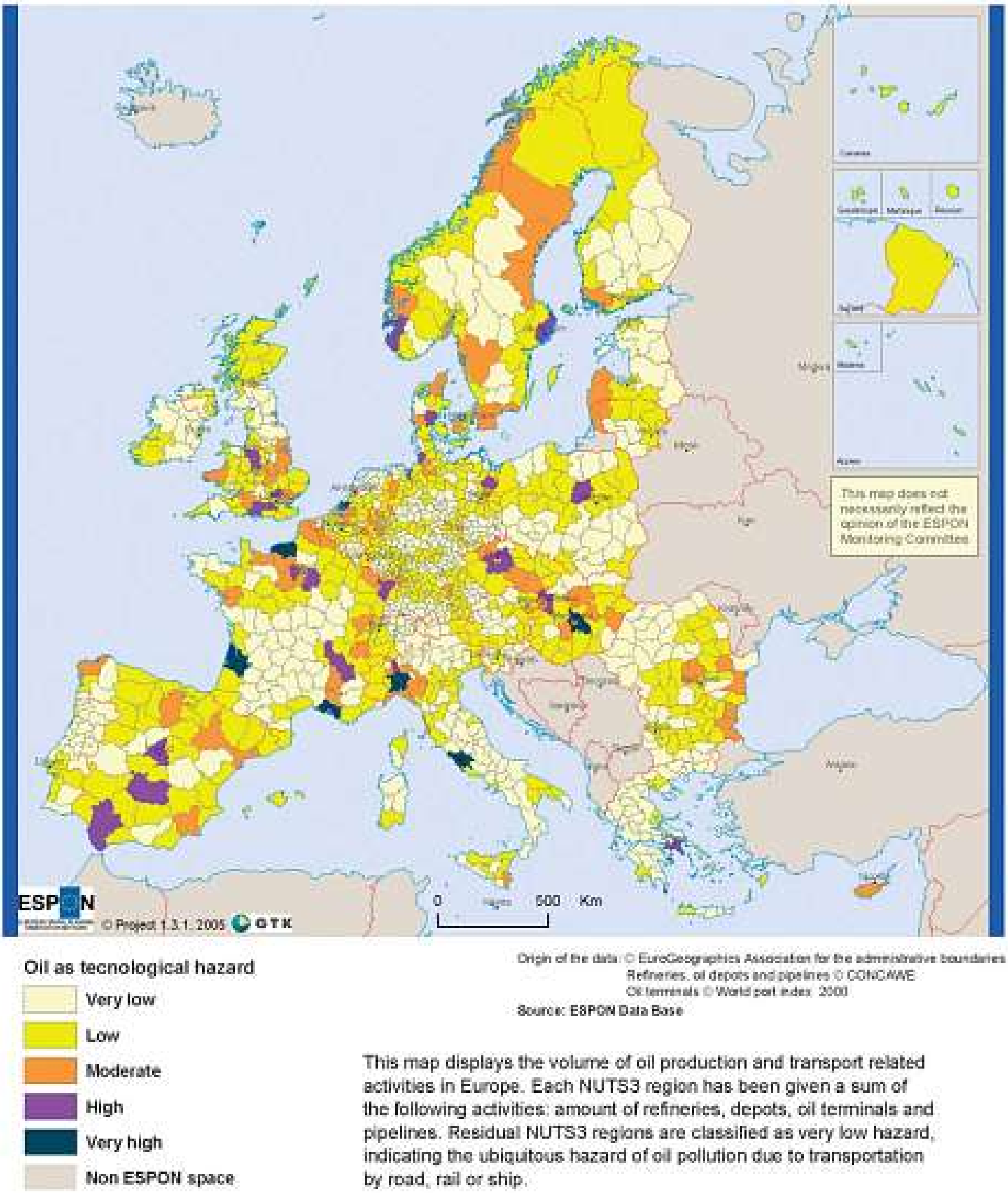
Table 18. Oil processing, transport and storage map classification.

Sum of refineries, oil harbours and pipelines	Hazard class
0	1 Very low hazard
3	2 Low hazard
4–6	3 Medium hazard
7–10	4 High
11–16	5 Very high hazard

Map analysis

The oil processing, storage and transport map shows that the hazard from oil contamination is rather widespread in the European territory, which is also based on the European economy's dependency on oil. However, not all coastal areas have oil-handling facilities. While the entire coast of the United Kingdom is under medium to very high hazard, large coastal areas in Italy have no hazard.

The map is a synthetic approach, as it focuses on the installations on land and not on offshore operations nor on the main shipping routes of tankers. The map assumes that the more onshore facilities, the higher the hazard, as most accidents happen during handling in ports (ITOPF 2005). Nevertheless, some areas potentially threatened by oil tanker accidents en route are well represented, like in the North Sea, the Baltic Sea, the Mediterranean and the Black Sea. The Oresund (water course between Denmark and Sweden) is one of the most frequented areas by oil transport in Europe and thus has a high hazard. Also, the English Channel is marked with a high hazard. The northwestern coast of Spain has a high hazard as well, which was sadly shown by the Prestige oil spill in 2002 (ITOPF 2005). Unfortunately, the adjacent areas in Portugal and France that also suffered from the spill are not represented because they disposed of oil terminals, refineries and/or pipelines. Bretagne is a difficult example, because this region has been hit by large oil spills even though there is no nearby oil handling facilities.



Map 15. Oil transport, storage and handling.

3 AGGREGATED HAZARD MAP

The purpose of the ESPON 1.3.1 Hazards project was to identify single and multi hazards relevant for spatial planning in Europe and to identify typologies of regions, as well as risk patterns. The hazard maps presented above allow initial analyses but they do not deliver an integrated picture. This chapter shows an approach for an aggregated hazard map of the EU 27+2 area. All of the hazards described above do not have the same level of importance in the spatial development of Europe. While some hazards have only local effects, others threaten larger areas or even all of Europe. Also, some hazards occur more frequently than others, and hazards are also perceived differently based on the potential danger they pose. For example, does hazard threaten human lives or technical assets, or do they create more local or mainly regional costs. It is also of great importance how does it the general public perceives a hazard.

Due to these differences, it was not possible to simply add up all of the hazards and then display them as an aggregated sum. The hazards were weighted by an anonymous group of 12 European experts on both hazards and spatial planning to determine their relevance for the entire European area. The applied weighting system was the so-called Delphi method. This weighting process was first developed in regional case study areas, (Olfert et al. 2006, *this volume* before being applied on the EU 27+ area). The result of the weighting process on EU 27+2 level is summarized in Table 19.

The results of this weighting process were categorised into five classes and their distribution, displayed according to percentile ranking, is shown in the Table 20.

Table 19. Results of hazard weighting on EU 27+2 level. Source: Schmidt-Thomé 2005.

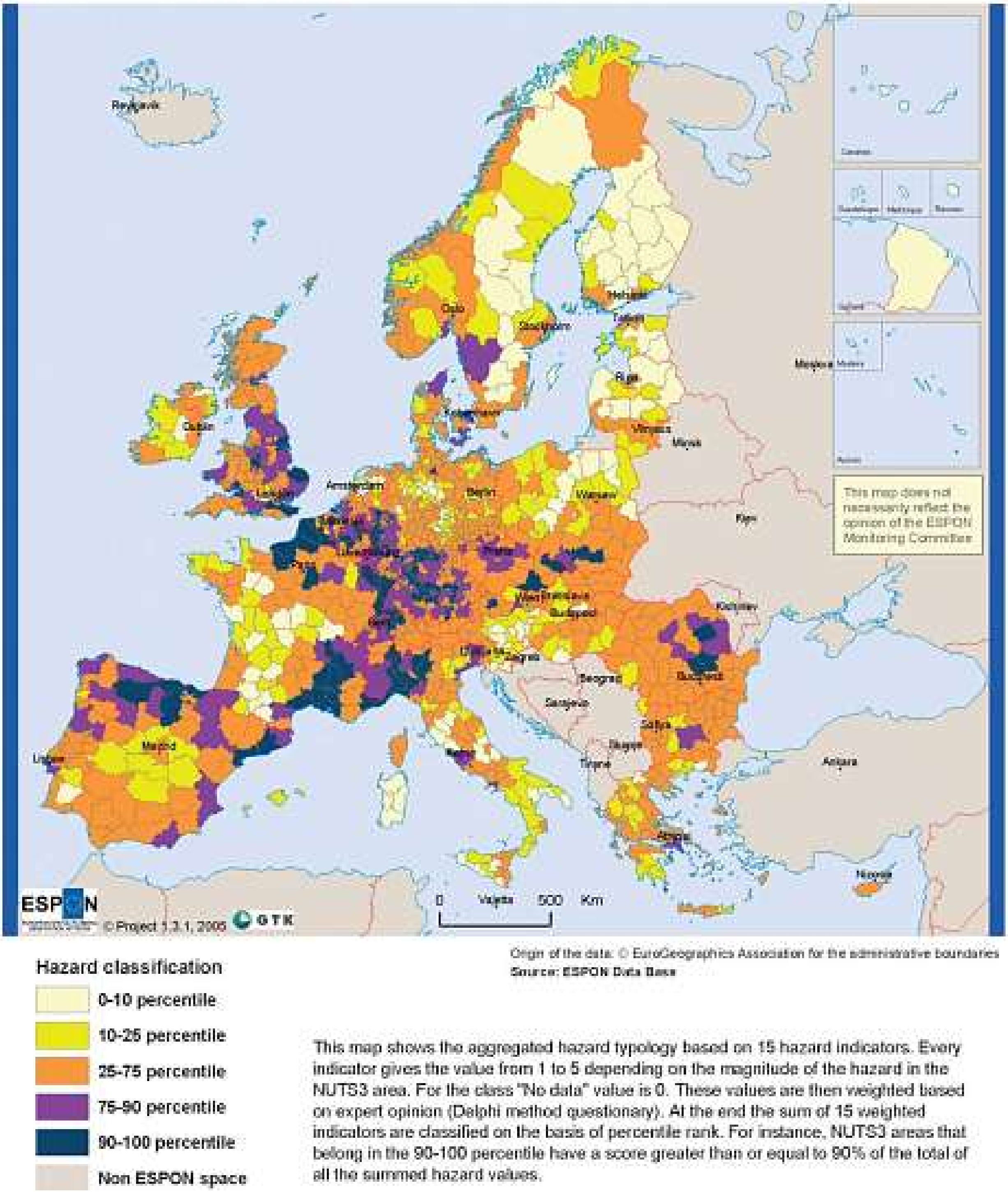
Hazards		**Average estimation**				**Quartile interval**		
		Round 1	**Round 2**	**Round 3 (final result)**	**Round 3 / Round 1 (%)**	**Round 1**	**Round 2**	**Round 3**
Natural Hazards	Avalanches	3,0	2,2	**2,3**	76,0	3,1	1,9	0,6
	Droughts	7,5	8,0	**7,5**	100,4	5,0	3,4	2,0
	Earthquakes	10,5	10,0	**11,1**	105,1	3,8	4,1	2,5
	Extreme temperatures	3,7	3,7	**3,6**	96,9	3,3	1,7	0,6
	Floods	15,0	16,1	**15,6**	103,9	3,5	2,4	1,0
	Forest fires	10,0	11,2	**11,4**	114,4	5,5	1,8	2,5
	Landslides	5,7	5,6	**6,0**	106,4	2,3	1,0	0,5
	Storm surges	4,2	4,1	**4,5**	108,6	4,0	1,6	0,0
	Tsunamis	1,4	1,1	**1,4**	105,0	1,1	0,0	0,1
	Volcanic eruptions	3,6	2,7	**2,8**	77,1	1,1	1,0	0,4
	Winter storms	6,9	8,7	**7,5**	109,1	3,5	6,7	2,0
Technological hazards	Air traffic hazards	4,0	2,7	**2,1**	52,6	2,9	1,6	1,2
	Major accident hazards	8,6	8,3	**8,4**	97,9	6,0	2,0	1,6
	Nuclear power plants	8,2	8,4	**7,8**	95,2	7,3	3,6	2,5
	Oil handling, transport and storage	7,6	7,3	**7,8**	102,0	3,3	2,5	1,4
	Sum	**100,0**	**100,0**	**100,0**		**100,0**	**100,0**	**100,0**

Table 20. Classification of aggregated hazards.

Percentiles of all weighted aggregated hazards, and distribution of scores (in brackets)	
<10 percentile (78–189)	1 Very low hazard
10–25 percentile (190–206)	2 Low hazard
25–75 percentile (207–252)	3 Medium hazard
75–90 percentile (253–273)	4 High hazard
90–100 percentile (274–339)	5 Very high hazard

Map analysis

The aggregated hazard map reveals three main high hazard corridors in the EU 27+2 area, all of which merge in central and southern Germany. One corridor starts off in the United Kingdom and includes parts of the Benelux countries; another one includes the Iberian Peninsula and stretches over southern France, northern Italy and Switzerland. The third corridor is more scattered but starts from central Germany towards the eastern EU member states where it then turns south over the accession countries into Greece. This pattern of high and very high natural hazards could be described as the shape of a scorpion, with its head in central and southern Germany, the arms and the claws reaching into coastal areas of United Kingdom and along the coastal areas of the Iberian peninsula, respectively, and the partial and rather scattered tail bending over eastern



Map 16. Aggregated hazard map.

Europe southwards into Greece. Outliers of this "high hazard scorpion" are located in southern Scandinavia and central Italy. Most of the NUTS 3 regions have a medium or low natural hazard potential and only a few a very low hazard potential, mainly parts around the Baltic Sea, western France, Sardinia and other scattered areas.

In the map analysis, one has to take into account that the 15 hazards used for these maps are based on current knowledge that is comparable among all EU 27+2 countries. Only four hazard types represent technological hazards. The map thus serves as an overview of the entire area, but regional and local analysis must always take the best available data into account. The ESPON Hazards project final report presents separate technological and natural aggregated hazard maps (Schmidt-Thomé 2005).

4 AGGREGATED RISK MAP

A common way to highlight the differences between risks and hazards is to stress their natural versus their anthropogenic element. Hazards are commonly understood as possible natural events with detrimental consequences whose causes are beyond human control, for example an earthquake. However, risks can also relate to dangerous situations caused by human activities, like the meltdown of a nuclear reactor. Humans in general have no influence on the occurrence or magnitude of an earthquake, but to live or work in an earthquake-prone area is a more or less conscious decision. This deliberate exposure is a conscious risk that is based on a natural hazard. Furthermore, natural hazards such as river flooding have a strong human causative element due to the straightening of rivers. Risks can therefore also be seen as "domesticated" hazards. The hazard concept stresses possible impacts of events on individuals, groups or communities and refers to a potentially damaging disaster. The risk concept emphasizes possibilities for active management (avoidance or mitigation) of harmful events and therefore renders hazards calculable and manageable. Thus, a hazard refers to an event while risk refers to probability (and to a range of methodological implications e.g. risk analysis and management).

The ESPON Hazards project defined risk as: Risk = Hazard potential x Vulnerability (Schmidt-Thomé 2005, Annex I). The following section presents an aggregated risk map of European regions that is a combination of the vulnerability map (Kumpulainen 2006, *this volume*) and the aggregated hazard map (Map 16).

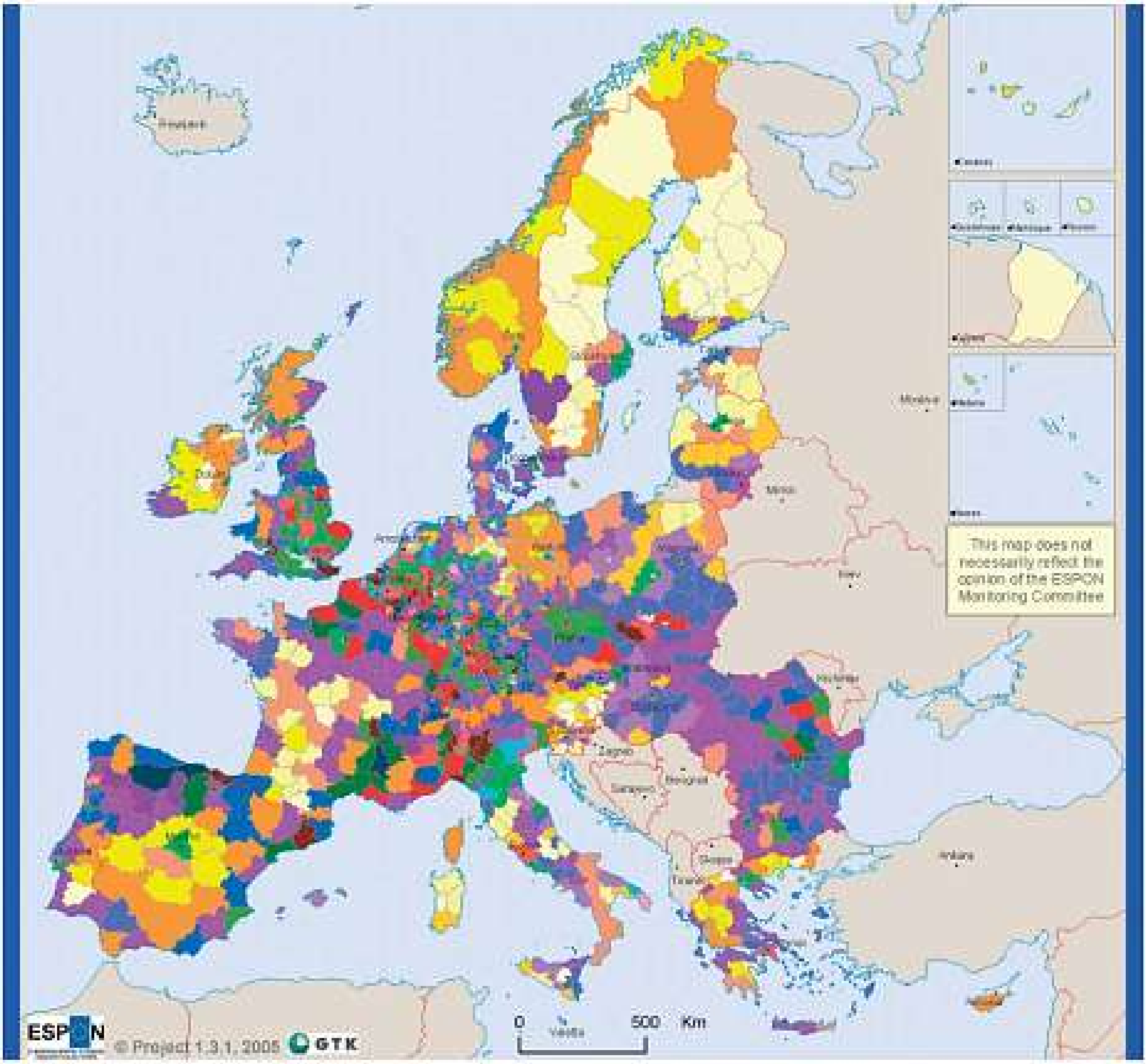
The risk map follows a legend that displays the hazard values on the y-axis and the integrated vulnerability (see Table 21) on the x-axis. The integrated vulnerability is plotted in a 50:50 relationship with the intensity of hazard X (see above for single hazard and aggregated hazard classifications). Thus, all classes with the same sum (e.g. 4, i.e classes 3+1, 2+2 and 1+3) have the same risk of a certain hazard. This leads to a distinction of 9 risk classes.

According to the integrated vulnerability map (Map 1 in Kumpulainen 2006, *this volume*), areas with a higher GDP per capita, a high population density and a high fragmentation have a higher vulnerability compared to those areas with lower GDP's, lower population density and lower fragmentation. Also, countries with a higher national GDP per capita have stronger response possibilities to hazards than those with a lower one. A further distinction between the 9 resulting risk classes is necessary to identify the source of the risk. A simple approach with 9 classes would not be useful to identity if a given risk class of a certain NUTS 3 area was based on its degree of vulnerability or on the respective hazard intensity. This might lead to similar risk classes of areas with, for example, a high risk but low hazard and those of lower risk but higher hazard intensities.

The risk map legend is therefore based on 9 major colour groups that are split into different shades. The lowest risk class, 2, is presented in very bright beige. Then yellow shades get darker towards orange, representing an increase in risk (classes 3 and 4). Classes 2, 3 and 4 belong to the low risk classes. The medium risk classes 5, 6, and 7 are represented in purple, blue and green, respectively, and high risk classes 8, 9 and 10 in red, maroon, and black. Darker shadings of the same colour group indicate higher hazard intensities, lighter shadings a higher vulnerability.

Table 21. Classification scheme of hazard and risk maps.

Legend of risk maps	Degree of vulnerability				
Intensity of hazard	1	2	3	4	5
1	2	3	4	5	6
2	3	4	5	6	7
3	4	5	6	7	8
4	5	6	7	8	9
5	6	7	8	9	10



Origin of the data: © EuroGeographics Association for the administrative boundaries
GDP 2000 Eurostat Newcronos Regio
Population density 1999 Eurostat Newcronos Regio
National GDP 2003 Eurostat
CLC90 EEA
Source: ESPON Data Base

Map 17. Aggregated risk map.

Integrated risk map analysis

The risk map is more complex to analyse than hazard or vulnerability maps, mainly because of the higher diversification due to the integration of the hazard potential and vulnerability. Nevertheless, certain patterns among the lower risk classes (2–4), the medium risk classes (5–7) and the high risk classes (8–10) can be distinguished.

The scorpion shape of high aggregated natural hazards (see above) is still visible in the aggregated risk map, but has partially shifted towards medium risk classes. In contrast to the aggregated natural hazard map, most parts of central and eastern of Europe are found in the medium risk classes, while many parts of southern, western and northern Europe belong to the lower risk classes. The "Pentagon Area" displays the highest agglomeration of high risk and the most extensive areas with the lowest risk are found in northern Europe.

When analysing the aggregated risk map, it should be taken into account that the data sets are based on 15 hazards, of which four are technological hazards (see above). The scale seems to be suitable for an inter-regional comparison, but a risk assessment for regional and local planning purposes has to be much more detailed (related to hazard intensity as well as vulnerability, which could relate more to a single protection of goods). Possible misleading influences are also the size differences of the NUTS 3 regions.

This article presents only one aggregated risk map, while it is certainly possible to generate single risk maps for all of the hazards described above. See examples for economic risk maps by Schmidt-Thomé et al. 2006a. The final report of the Espon 1.3.1 Hazards project (Schmidt-Thomé 2005) also presents aggregated natural hazard and technological hazard risk maps.

5 CONCLUSION AND FURTHER RESEARCH

The methodology developed by the ESPON 1.3.1 Hazards project to display single and aggregated hazards and risks on regional scale provide a first overview on the EU 27+2 area. It has to be kept in mind that the primary goal remains the European wide perspective and overview. The hazard and risk maps can be used to determine possible adverse effects of spatial development and can contribute to the diversion of funding for hazard reduction.

This first approach of mapping hazards in a pan-European perspective on this scale should lead to further research and consequently improvement of data quality. Since natural and technological hazards play a major role in regional development and sustainability of investments, hazard maps could be used in structural funding and other spatial development strategies. In this way, the potential objectives of sustainable development can be identified and mitigated at an early stage.

The maps presented in this report show trends of occurrences and agglomerations of hazards and risks. EU funding programmes, such as INTERREG, can use funds to promote more focussed hazard and risk research activities in over regional and cross border areas (Schmidt-Thomé et al. 2006 b.)

Many datasets used for this project should be improved, both in terms of precision and completeness. The aim of the ESPON Hazards project was to obtain a first overview on hazards and risk on the entire ESPON space (EU 27+2 countries), thus all hazard maps that are presented here are preliminary examples that require further development.

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VULNERABILITY CONCEPTS IN HAZARD AND RISK ASSESSMENT

by
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Kumpulainen, S. 2006. Vulnerability concepts in hazard and risk assessment. Natural and technological hazards and risks affecting the spatial development of European regions. *Geological Survey of Finland, Special Paper 42,* 65–74, 2 figures, 1 table, 1 map.

Vulnerability is an essential part of hazards and risk research and refers to the susceptibility of people, communities or regions to natural or technological hazards. The ESPON Hazards project defines vulnerability as combination of damage potential and coping capacity, but it also appreciates the versatile nature of vulnerability by acknowledging three vulnerability dimensions (economic, social and ecological). To measure vulnerability, indicators that cover both damage potential and coping capacity, as well as the range of all three vulnerability dimensions were used. Weighting and combining the feasible indicators created an integrated vulnerability index and an integrated vulnerability map to depict the vulnerability of all regions of the EU 27+2. The map was further combined with an aggregated hazards map to create the aggregated risk map of Europe.

Key words: natural hazards, risk assesment vulnerability, damage potential, coping capacity, Europe

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1 VULNERABILITY IN THE ESPON HAZARDS PROJECT

The ESPON Hazards project (2003:19) defines vulnerability as the degree of fragility of a person, a group, a community or an area towards defined hazards. Vulnerability is a set of conditions and processes resulting from physical, social, economic and environmental factors that increase the susceptibility of a community to the impact of hazards. Vulnerability also encompasses the idea of response and coping, since it is determined by the potential of a community to react and withstand a disaster.

One of the ESPON Hazards project's primary goals was to produce an aggregated risk map of the EU 27+2, which shows the degree of risk for each European NUTS3 region. The project defines risk as the combination of hazard potential and vulnerability:

Risk = Hazard potential x Vulnerability

The map is based on an aggregated hazard map and an integrated vulnerability map, and it enables us to see whether the level of risk is related to a region's hazard potential, its vulnerability or both.

To be able to portray the vulnerability of European NUTS3 -regions on a map, it has been important to consider regional vulnerability as extensively as possible. The Hazards project acknowledges damage potential and coping capacity as the two main components of vulnerability:

Damage potential + coping capacity = regional vulnerability

At the same time, the project recognizes three dimensions of vulnerability: economic, social and ecological (ESPON Hazards project 2004 & Schmidt-Thomé 2005).

The economic dimension of vulnerability acknowledges economic damage potential, which can be understood as anything concrete that affects the economy of a region and can be damaged by a hazard. The economic dimension of vulnerability represents the risk to production, distribution and consumption.

Comfort et al. (1999) acknowledge the fact that advanced industrial societies, especially large urban centres, are especially vulnerable because the destruction of important and extensive systems of communications and infrastructure is costly and can have vast consequences on the economic stability, even on the global scale. The economic dimension offers an interesting approach to regional vulnerability, especially from the insurance company point-of-view of damage potential.

The social dimension of vulnerability acknowledges the vulnerability of people, and the emphasis is on coping capacity. Especially weak and poor population groups are considered vulnerable. Social vulnerability has to do with the different features of human beings.

Blaikie et al. (1994:9–10) argue that the most vulnerable groups are those who find it hardest to reconstruct their livelihood after a disaster. They find that, as a rule, the poor suffer more from hazards than the rich (see also Yohe & Tol 2001:8). The time dimension is relevant since reconstruction in poor areas can take a long time, which affects the economy and livelihood of the area drastically. Further, the poorer population groups do not always have a choice of where to locate, thus they might have to live in risky areas, for example on a muddy hillside or a flood plain (cf. environmental justice). Cross (2001) argues that people in small towns and rural communities are more vulnerable than people in large cities because of weaker preparedness.

Cannon et al. (2003) see social vulnerability as a complex set of characteristics that includes a person's initial wellbeing, livelihood and resilience, self-protection, social protection and social and political networks and institutions. Cutter et al. (2003) define social vulnerability as "a multidimensional concept that helps identify those characteristics and experiences of communities (and individuals) that enable them to respond and recover from natural hazards".

The ecological dimension of vulnerability acknowledges ecosystem or environmental vulnerability or fragility. In the case of ecological vulnerability, it is important to find out how different kinds of natural environments cope with and recover from different hazards.

According to Williams & Kaputska (2000), ecosystem vulnerability can be seen as "the inability of an ecosystem to tolerate stressors over time and space". Villa & McLeod (2002) state that environmental vulnerability can be either intrinsic or extrinsic. Intrinsic vulnerability is related to factors internal to the system (ecosystem health and resilience), whereas extrinsic vulnerability contains factors external to the system (present exposure and external hazard). Ecological vulnerability thus recognizes both ecological damage potential and coping capacity.

1.1 Other approaches to defining vulnerability

The field of vulnerability research embraces an array of different definitions for vulnerability. Blaikie et al. (1994:9) define vulnerability as "the characteristics of a person or group in terms of their capacity to anticipate, cope with, resist, and recover from the impact of a natural hazard".

According to the UNDP Bureau for Crisis Prevention and Recovery (UNDP 2004:11), human vulnerability is "a condition or process resulting from physical, social, economic and environmental factors, which determines the likelihood and scale of damage from the impact of a given hazard". This definition also encompasses response and coping, since vulnerability refers to the different variables that make people less able to absorb the impact and recover from a hazard event.

According to Cutter (1996), vulnerability is broadly defined as "potential for loss". However, vulnerability is understood in different ways and Cutter has found three distinct themes in vulnerability research (1996:530–533):

1. Vulnerability as hazard exposure: Research under this theme concentrates on the distribution of some hazardous condition, on human occupancy of such an area and on the degree of loss associated with a hazardous event. Vulnerability is a pre-existing condition.
2. Vulnerability as social response: Research under this theme concentrates on response and coping capacity, including societal resistance and resilience to hazards as well as recovery from a hazardous event. This approach highlights the social construction of vulnerability.
3. Vulnerability of places: Vulnerability of places is a combination of hazard exposure and social response within a specific geographic area.

The ESPON Hazards project can be viewed as a representative of the third, integrative approach. Vulnerability in the Hazards project is place-specific and it takes into account the damage potential (including human occupation, infrastructure and natural areas) and coping capacity of regions. The areal unit for the project is a so-called NUTS3 region, but the results are shown on maps of the EU 27+2.

Cutter (1996 , et al. 2003) has drawn together the different elements that contribute to the overall vulnerability of places in the hazards-of-place model of vulnerability (see Figure 1). Here, risk (likelihood of a hazard event) and mitigation (measures to reduce risk and/or its impacts) are combined to create hazard potential. The hazard potential is filtered through the geographic context (site and situation, proximity) and the social fabric of society (socioeconomic

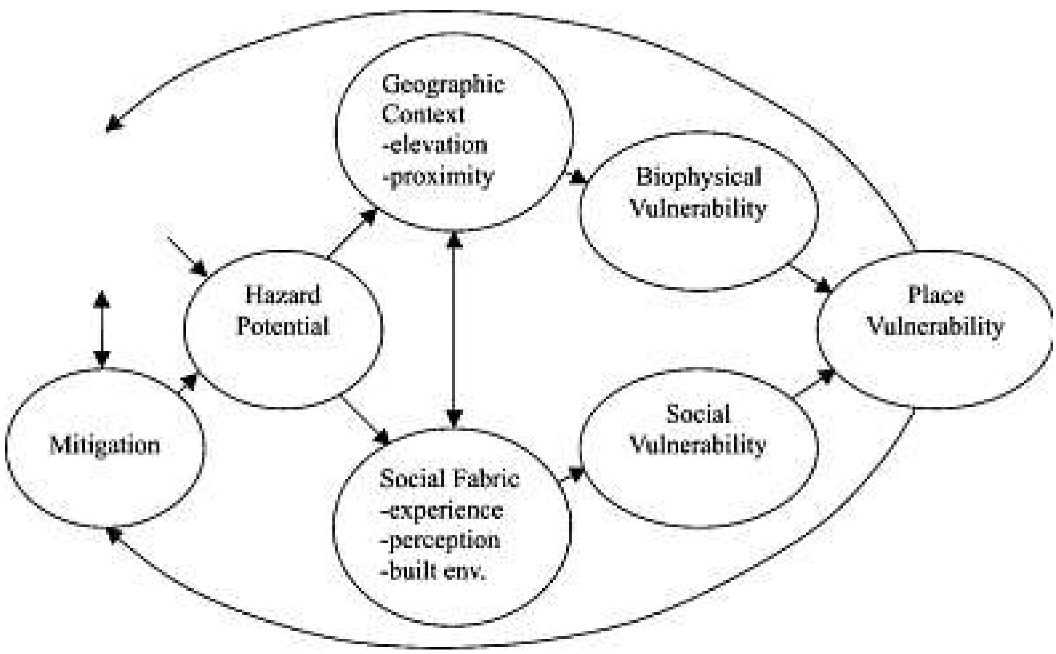


Fig. 1. The Hazards-of-Place model of vulnerability (Cutter et al. 2003).

indicators, risk perception, ability to respond) and either moderated or enhanced by them. Biophysical vulnerability and social vulnerability together form the overall place vulnerability.

The hazards-of-place model of vulnerability has an explicit focus on locality, since it depicts the overall situation and elements contributing to the vulnerability of a specific geographical area. The ESPON Hazard project's approach is similar, as it has combined hazards and the different elements of vulnerability to come up with a typology to depict regional risk. However, the definitions of risk and hazard potential differ in these two approaches. Cutter's risk, "the likelihood of occurrence (or probability) of the hazard" (1996:536), corresponds with the Hazard project's definition of hazard potential (magnitude and frequency). Cutter's hazard potential is a combination of risk and mitigation, where the Hazards project's risk is a combination of hazard potential and vulnerability.

1.2 Measuring vulnerability in the Hazards project

Vulnerability can be measured by a range of indicators. In the ESPON Hazards project, overall regional vulnerability is measured as a combination of damage potential and coping capacity. The basic criteria for choosing vulnerability indicators was that they should cover both damage potential and coping capacity, as well as the range of all three vulnerability dimensions.

Damage potential indicators measure anything concrete that can be damaged by a hazard and measure the scale of possible damage in a particular region. Coping capacity indicators measure the ability of a community or a region to prepare or respond to a hazard. They measure either human properties or the existence of infrastructure. At the same time, coping capacity indicators point out social and place inequalities. The indicators are introduced in Table 1.

The table shows for each indicator whether it represents damage potential or coping capacity. One indicator, tourism, can be considered both a damage potential indicator and a coping capacity indicator. Tourists affect the damage potential of a region since they are a population group in danger due to their lack of knowledge of local conditions and due to the fact that popular tourist sites are often in risky areas (see e.g. White and Hass 1975). During the Indian Ocean earthquake and tsunami of December 26th 2004, both the locals and the tourists had no previous experience with such a natural hazard. However, the damage potential of many regions was especially high because the tourist dwellings and attractions were located on the coast, where the tsunami hit.

Tourists affect the coping capacity of a region since they have, in most cases, no knowledge of how to cope in the event of a hazard, and they often don't know the region or the language and may not receive the necessary information to cope with the situation. Further, tourism is an important source of income for many regions, and a catastrophe can have severe and long-term effects for the regional economy and coping capacity in the long-term.

Table 1 further points out which of the three dimensions each indicator represents. In the case of damage potential indicators, it was pretty simple to point out the dimension for each indicator, although population density and tourism can be connected to either the economic or the social dimension. In the case of the six last coping capacity indicators of Table 1, it was not possible to pinpoint them to any of the three dimensions. All of these indicators measure mitigation and preparedness of the society, especially its infrastructure.

The vulnerability of natural areas is not easily measurable, especially since not all hazards pose a threat to the environment. ESPON project 1.3.2 (Territorial trends of the management of the natural heritage) states that "the only spatially-specific and methodologically consistent units available for environmental reporting are land areas that are distinguished either by their protection or designation status or by their land cover type." (ESPON Natural Heritage project 2004:102). The two indicators for the ecological dimension in Table 1, significant natural areas and fragmented natural areas, measure the vulnerability of the environment in two different ways, as referred to by the Natural Heritage project. Since there was no extensive and feasible data available on protected or otherwise significant natural areas, the Hazards project chose to use data on land cover type. The idea was that natural areas that are small and fragmented are vulnerable, since they are likely to be totally destroyed if a hazard strikes. However, some people argue that large, non-fragmented areas are more vulnerable than small frag-

Table 1. Possible indicators for measuring vulnerability in the ESPON Hazards project.

Indicator	**dp/ cc[1]**	**econ/soc/ ecol[2]**	**Description**	**Data avail-ability**
GDP/capita	dp	econ	High GDP/capita measures the value of endangered physical infrastructure and the extent of possible damage to the economy. Insurance company point of view.	+
population density	dp	econ/ soc	Measures the amount of people in danger.	+
tourism (e.g. number of tourists/number of hotel beds)	dp/ cc	econ/ soc	Tourists or people outside their familiar environment are especially vulnerable for two main reasons. First, they are generally unaware of the risks and don't necessarily understand the seriousness of hazardous situations. They don't necessarily know the local language and thus they are likely to miss important information. Secondly, tourist dwellings are often located in high-risk areas and might not meet the requirements of structural risk mitigation.	+/–
culturally significant sites	dp	econ	Such sites are unique and important for the cultural and historical identity of people, e.g. sites on the UNESCO world heritage list.	+/–
significant natural areas	dp	ecol	Areas with special natural values (e.g. national parks or other significant natural areas) can be considered vulnerable because they are unique and possibly home to rare species of flora of fauna.	+/–
fragmented natural areas	dp	ecol	Natural areas that are small and fragmented are vulnerable, since they are likely to be totally destroyed if a hazard strikes.	+
GDP/capita	cc	soc	Low GDP/capita measures the capacity of people or regions to cope with a catastrophe. In the Hazards project, the national GDP/capita was used because the presumption was that coping capacity is weak in poor countries and strong in rich countries. It was further presumed that there are no marked differences in coping capacity inside a country.	+
education rate	cc	soc	Measures people's ability to understand and gain information. The presumption is that people with a low educational level do not find, seek or understand information concerning risks as well as others, and are therefore vulnerable.	+/–
dependency ratio	cc	soc	Measures the proportion of strong and weak population groups. A region with a high dependency ratio is especially vulnerable for two reasons. First, elderly people and young children are physically frail and thus vulnerable to hazards. Secondly, elderly people and children may not be able to help themselves but need help in the face of a hazard. A region with a high dependency ratio is dependent on help from the outside.	+/–
risk perception	cc	soc	Indicates how people perceive a risk and what their efforts have been to mitigate the effects of a hazard.	–
institutional preparedness	cc		Indicates the level of mitigation of a region.	–
medical infrastructure	cc		Indicates how a region is able to respond to a hazard (e.g. number of hospital beds per 1000 inhabitants or number doctors per 1000 inhabitants).	+/–
technical infrastructure	cc		Indicates how a region is able to respond to a hazard (e.g. number of fire brigades, fire men, helicopters etc.).	+/–
alarm systems	cc		Indicates the level of mitigation of a region.	+/–
share of budget spent on civil defence	cc		Indicates the level of mitigation of a region	+/–
share of budget spent on research and development	cc		Indicates the level of mitigation of a region.	+/–

[1] dp = damage potential, cc= coping capacity
[2] econ = economic dimension, soc = social dimension, ecol = ecological dimension of vulnerability

mented areas due to their high importance to the whole ecosystem.

In an ideal situation, it would be possible to use all the indicators of Table 1 to measure vulnerability. The right-hand column in Table 1 shows the status of data available for each of the indicators within the ESPON Hazards project. Plus (+) stands for indicators where data was available and the indicator was used in the project. Minus (–) stands for indicators that could not be used due to a lack of data or difficulties in quantification (e.g. institutional preparedness and risk perception are in practice impossible to measure). Plus/minus (+/–) stands for indicators where data was available, but not feasible for the Hazards project. The most common problem was that the data was only available on a NUTS2, NUTS1 or NUTS0 level, but not on the NUTS3 level. Further, if there was NUTS3 data, it didn't necessarily cover the whole EU 27+2 area.

1.3 Other approaches to measuring vulnerability

There exists a range of different approaches to measure vulnerability. Two innovative approaches are introduced here.

Cutter et al. (2003) have concentrated on measuring social vulnerability, which is an integral part of the Hazards-of-place model. Here, social vulnerability includes both social inequalities (social factors that influence the susceptibility of population groups to harm and that affect their ability to respond) and place equalities (characteristics of communities and the built environment, such as level of urbanization and economic vitality). This definition includes both the social and economic vulnerability dimensions of the Hazard's project, although damage potential has a slightly smaller role in the model.

According to Cutter et al. (2003), vulnerability research has given much more attention to the study of biophysical vulnerability and the vulnerability of the built environment than to the study of social vulnerability. One obvious reason for this are the difficulties in quantifying and measuring social vulnerability. With the SoVI model, Cutter et al. have been able to compare the social vulnerability of all counties in the US using a statistical analysis of 42 independent variables. The strength of this approach lies in the multitude of variables and in the fact that the authors have been able to explain 76,4% of the variance among US counties with the help of 11 factors (e.g. personal wealth, age, density of the built environment, single-sector economic dependence). The SoVI index does not take hazard event frequency or magnitude into account, but Cutter at al. suggest expanding the model by adding both hazards as well as economic loss data to the model.

A second interesting model is UNDP's Disaster Risk Index (DRI), which measures and compares the physical exposure to hazards, vulnerability and risk between countries (UNDP 2004). Here, physical exposure refers to the number of people located in areas where hazardous events occur combined with the frequency of hazard events. In this model, population density is not seen as an indicator of vulnerability, but a condition for a disaster risk to exist. Vulnerability explains why, with a given level of exposure, people are more or less at risk. Vulnerability refers to the different variables that make people less able to absorb the impact and recover from a hazard event. These may be economic (lack of reserves), social (weak social organisation), technical (poorly constructed housing) or environmental (fragility of ecosystems).

The prime reason for developing the DRI was to improve the understanding of the relationship between development and disaster risk. With a separate analysis of four natural hazards, it became clear that disaster risk (risk of death in disaster) is considerably lower in high-income countries than in medium-or low-income countries. Further, it was found out that for example in the case of earthquakes, countries with high urban growth rates and high physical exposure can be associated with high levels of risk. The DRI is innovative for two reasons: it takes into account the development aspect and it uses a different set of vulnerability indicators for each hazard.

2 INTEGRATED VULNERABILITY INDEX AND MAP

The indicators in Table 1 marked with a plus (+) were used in the ESPON Hazards project to create an integrated vulnerability index and an integrated vulnerability map. To combine the four feasible indicators (marked with + in Table 1), the indicators needed to be weighted in a way that the overall regional vulnerability is 100%.

There are different methods for the weighting process. One possibility is not to assign different weights for the different indicators but to use an additive model, as Cutter et al. (2003) did in their SoVI index. In this case, all indicators received the same value. Another possible way to weigh the indicators is to use the Delphi method. This method was used in the Hazards project as a tool to weight hazards on regional and European levels, as well as to weight vulnerability components on the regional level. The decision not to use the Delphi method on the European level of vulnerability was mainly made on the basis of the case study results. Although the experts were able to assess the relevance of different hazards in their regions, they had difficulties deciding on the significance of different vulnerability components. It seems that not everybody was familiar with the concept of regional vulnerability, which made the task of weighting difficult. A European-level Delphi on vulnerability would most probably have proven too difficult for the experts, who would have had to consider the joint vulnerability of all NUTS3 regions in EU27+2.

In the ESPON Hazards project, the weighting was done by testing different weighting combinations for the four feasible indicators. The resulting sample maps allowed for the comparison of the different combinations and showed possible changes in the overall vulnerability of different regions. This "sensitivity test" was done with the following four combinations:

1. 30 + 30 + 10 + 30 (regional GDP, population density, fragmented natural areas, national GDP)
2. 25 + 25 + 25 + 25
3. 20 + 20 + 10 + 50
4. 20 + 50 + 10 + 20

Ideally, all four indicators would receive the same value of 25%, which altogether adds up to 100% regional vulnerability. However, due to the fact that the indicator fragmented natural areas only depicts one aspect of ecological vulnerability, the indicator was given the percentage value of 10. Each of the other three indicators was given the percentage value of 30. Figure 2 shows the integrated vulnerability index with the four feasible indicators.

The integrated vulnerability index was used to create the integrated vulnerability map for the EU 27+2. Map 1 depicts the vulnerability of all regions individually. The map was further combined with an aggregated hazards map to create the aggregated risk map for Europe.

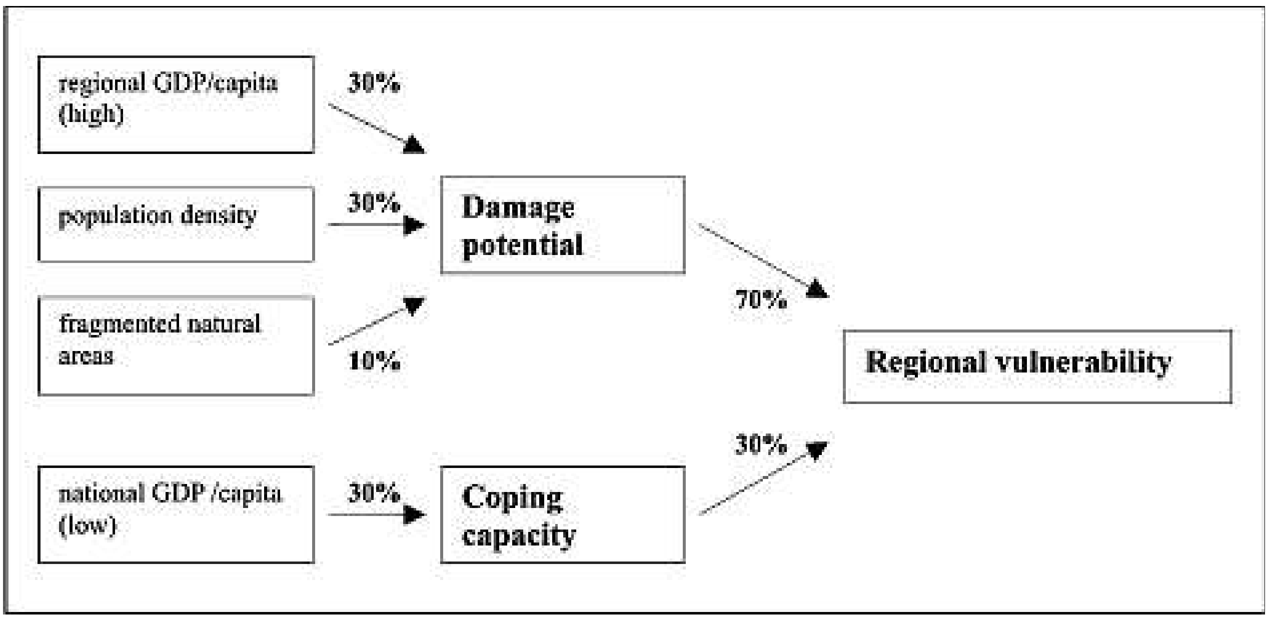
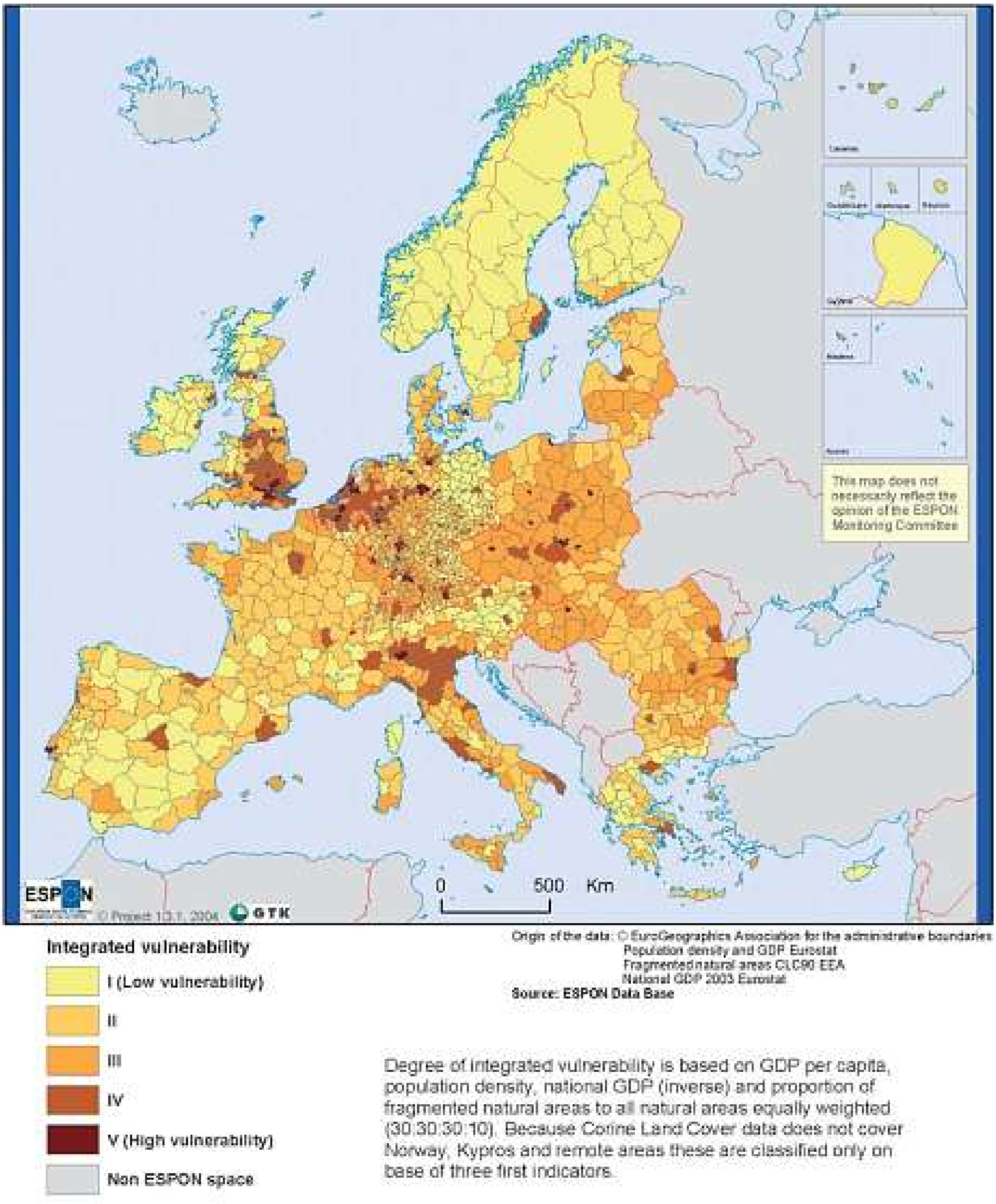


Figure 2. Integrated vulnerability index (~~ESPON Hazards project 2005~~Schmidt-Thomé 2005).



Map 1. Integrated vulnerability map (Schmidt-Thomé 2005). Map production Hilkka Kallio, GTK.

3 FUTURE RESEARCH NEEDS: HAZARD-SPECIFIC VULNERABILITY

In the future, it would be interesting to take a closer look at the hazard-specific nature of vulnerability. Although hazard-specific vulnerability is not a widely used concept in vulnerability research, it is possible to recognize at least two different approaches:

1. hazard centred: considering the relevant vulnerability indicators for a chosen hazard
2. region centred: first considering the hazards and then the hazard-specific vulnerability of a chosen region.

One example of the hazard-centred approach is the Disaster Risk Index of the UNDP (2004:32), which uses hazard-specific vulnerability indicators. The assumption is that factors that make people vulnerable to hazards are different for each hazard. The approach is hazard centred, since it considers three hazards (earthquakes, tropical cyclones and floods) and feasible vulnerability indicators for each of these hazards. The approach has also an areal connection, since in the DRI countries are indexed for each hazard type, for example, according to their relative vulnerability. Altogether 26 indicators were used for four hazards.

An example of the region-centred approach is Stock's (2003) analysis of the regional vulnerability in one German state (Nordrhein-Westfalen) with regard to climate change. The approach is region centred, since the starting point is the hazard potential and vulnerability of the municipalities in Nordrhein-Westfalen. This approach considers hazards related to weather and the idea is to determine the vulnerability of different sectors of the economy. According to Stock (2003:49), those parts of the natural environment and human existence that are sensible to weather determine the level of vulnerability of the region in question. One example of this approach is a map of the region that depicts those forested areas most vulnerable to storms.

The ESPON Hazards project has an a_real approach to vulnerability, to analyse the hazard potential, vulnerability and risk of all NUTS3 regions in the EU 27+2. However, the approach is not hazard-specific since the same vulnerability indicators are used in all regions and for all hazards. Using a hazard-specific approach would be especially useful when considering the vulnerability of a specific region (e.g. one NUTS3 region). In the Hazard project's case-study areas, the chosen methodology seemed somewhat general to bring out the essential results on the regional level. For example, a region in central Portugal plagued by forest fires needs to consider different vulnerability indicators than a region in southern Finland characterized by several technological hazards.

In addition to taking a closer look at the regional level, it is important to note that each hazard poses a different threat to different aspects of human life and the environment. For example, natural hazards are not necessarily a risk to natural areas, since forest fires, for example, are nature's way of clearing old forests and maintaining ecological diversity. However, some natural hazards can be enhanced by technology or intensified by a technological hazard, for example, a flood that reaches a chemical plant poses a severe threat to the environment. In the case of economic vulnerability, it would be interesting to consider damage potential of different sectors of economy. For example, oil spills are a threat especially to fishery and tourism, whereas agriculture can suffer severely and widely from floods and storms.

For a better knowledge of vulnerability in Europe, it would be interesting to take a look at the relevant hazards separately and consider the hazard-specific vulnerability for each of them. Further, hazards and vulnerability could be considered separately for specific regions, which would allow for the creation of regional risk profiles.

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INTEGRATED RISK ASSESSMENT OF MULTI-HAZARDS: A NEW METHODOLOGY

by
Stefan Greiving[1]

Greiving, S. 2006. Integrated risk assessment of multi-hazards: a new methodology. Natural and technological hazards and risks affecting the spatial development of European regions. *Geological Survey of Finland, Special Paper 42,* 75–82, 2 figures, 1 table.

The goal of this risk assessment approach is to determine the total risk potential of a sub-national region. This means aggregating all relevant risks (from earthquakes, floods etc.) to determine an integrated risk potential. The approach includes risks related to both natural and technological hazards, but excludes risks with no real spatial underpinning (e.g. epidemics). Thus, this is an integrated risk assessment of spatially relevant hazards.

Key words: natural hazards, technological hazards, vulnerability, risk assessment

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1 INTRODUCTION

The approach was elaborated upon and applied across Europe in the context of the project "Spatial effects of natural and technological hazards in general and in relation to climate change", which is part of the European Spatial Planning Observation Network (ESPON, www.espon.lu). An aggregated hazard, an integrated vulnerability and finally an aggregated risk map are presented as key results of this research project. Vulnerability is understood as a key component of risk and consists of hazard exposure and coping capacity.

2 BACKGROUND OF THE APPROACH

As discussed in detail by Greiving & Fleischhauer in this volume, spatial planning has to incorporate risks that are caused by natural or technological hazards in decision-making. Such spatially oriented risk management is defined as adjustment policies that intensify efforts to lower the potential for loss from future extreme events. However, for such decision-making an analytic, scientific approach seems to be indispensable. Is there appropriate data, are the necessary data and assessment methods available (e.g. hazard maps, risk maps) for developing a scientifically correct foundation for the decision making process? Due to the nature of spatial planning a multi-hazard risk approach is needed. All relevant hazards that threaten a certain area as well as the vulnerability of this area have to be considered instead of an area of science (sectoral, like in many natural sciences).

In this context, several multi-risk assessment approaches have been recently developed, for example:

the global disaster risk index,
http://www.undp.org/bcpr/disred/english/publications/rdr.htm
the ECHO approach,
http://europa.eu.int/comm/echo/field/dipecho/index_en.htm
the hotspot study,
http://publications.worldbank.org/ecommerce/catalog/product?item_id=4302005
the HAZUS MH, see
http://www.fema.gov/hazus/

However, these projects aim more at priority setting for aid funding than at providing an analytic basis for risk management in spatial planning.

Since the 1970's, geographers have developed integrative approaches for assessing hazards within their spatial context ('hazards of place') (Hewitt & Burton, 1971, Cutter & Solecki, 1989). However, further methodological elaborations on this subject have rarely been attempted, as pointed out by Cutter (1996). However, a multi hazard approach has not been addressed by the discipline of spatial planning for many years, especially in Europe. Although there is a tradition of spatial planning research in the context of single hazards (coastal flooding, river flooding, earthquakes, nuclear power plants), a synthetic consideration of spatially relevant hazards has only recently been addressed by a few authors (Egli, 1996, Burby et al., 1998, Greiving, 2002, Fleischhauer, 2004). One main reason for this recent change in perception is the realization that risk potentials are increasing and that it is not sufficient to restrict risk policies only to the response phase of the emergency management cycle. To promote sustainable development, hazards must be mitigated– a task for which spatial planning has to develop appropriate tools.

In spatial planning practises in Europe, little attention is paid to multi-risk approaches. Only in France and Switzerland is the multi-hazard approach established as part of current planning practise. In France, the aggregated hazard potential is indicated on a regional scale by a simple addition of the different single hazards (no attention is paid to the hazard intensity). This indicates an obligation for the elaboration of a risk prevention plan on the local level, which has binding effects for land-use planning (Fleischauer, Greiving & Wanczura 2005). In Switzerland, the appropriate sectoral planning body provides several single hazard maps. Within urban land-use planning, three hazard zones are designated (red zones, which indicate a high hazard potential, blue zones for medium and yellow zones for low). These zones are interlinked with certain settlement restrictions (e. g. prohibition of any new development in red zones). These hazard zones are based on overlaid single hazard maps. Thus, each area that may potentially be heavily threatened by a certain hazard (floods, avalanches, or landslides) is integrated in the "red zone", and designated in the urban land-use plan ("Nutzungsplan"). However, cumulative effects are not the focus of the Swiss methodology (Schaller 2003). Moreover, in both France and Switzerland, the planning practises focus on the multi-hazard assessment while vulnerability is excluded.

In view of this rare and incomplete state in multi-risk assessment for spatial planning, the need for a new, innovative tool is clearly visible. Harmonised risk assessment methodologies can be understood in this context as crucial for aiming at valid and comparable results of risk assessments within a threatened area.

3 STRUCTURE AND METHODOLOGY

3.1 General remarks

A spatial approach to risk is of high relevance for those authorities and stakeholders that act in a spatial context. This encompasses those persons or institutions that make spatially relevant decisions, typically involving large amounts of data and complex decision-making processes including normative weighting procedures. These actors may be interested in a spatial risk assessment approach because they are charged with ensuring spatial development (land-use planning, regional development funding) or with insuring spatial structures (offering insurance or re-insurance services).

A spatially oriented risk assessment methodology has four main characteristics. First, it has to be multi-hazard oriented, which means that it is must go beyond sectoral considerations of risks (Greiving 2002 and Schmidt-Thomé 2005). Second, only those risks that have a spatial relevance are considered. This means that ubiquitous risks like epidemic diseases or traffic accidents are not the focus of the analysis. Third, only collective risks that threaten a community as a whole are relevant and not individual risks like driving in a car or smoking. Finally, an integration of risk components (hazards and vulnerability) is necessary. Fig. 1 indicates how the different components are defined and interlinked:

The multi-risk approach is a harmonised assessment methodology that must be understood. This approach aims at assessing the risk potential of a certain area by means of aggregating all spatially relevant risks that are caused by natural and technological hazards.

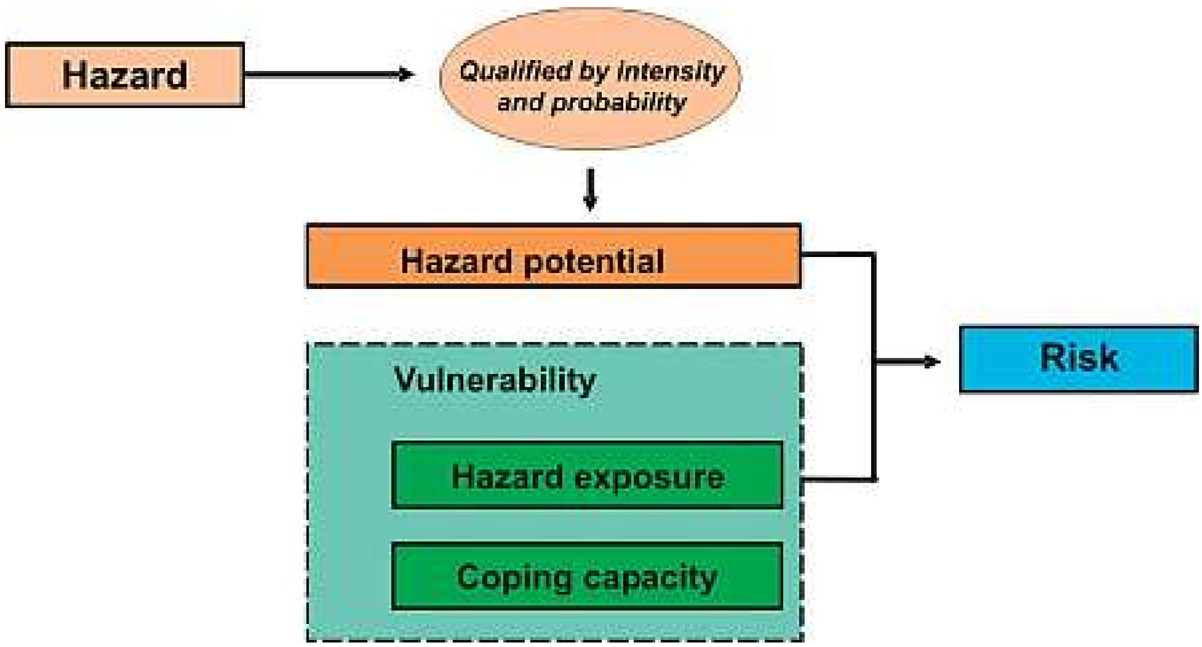

Fig. 1. Components of risk. Source: Schmidt-Thomé (2005).

The multi-risk approach was developed at the University of Dortmund and applied and adjusted for a supranational risk assessment at the regional level, to assess the integrated risk potentials of the approximately 1,500 NUTS-31 regions of the enlarged European Union (EU-27+2) for the ESPON hazards project (Schmidt-Thomé, 2005). In principle, however, the methodology can be applied at any geographical level and for any hazard and risk related purpose (as demonstrated by the Portuguese regional example, see Batista et al. 2004). Generally speaking, the presented approach is able to provide risk comparisons on each spatial level. However, the application on a Europe-wide level aims at a comparison between the different NUTS3 regions in the EU 27+2., The multi-risk approach can be used for regional or local spatial planning by using adjusted indicators and data.

On the presented level of application, the European Commission itself can be understood as the main target group. Risk management should be made an integral and explicit part of the EU cohesion policy (see also chapter 12). This calls for better coordination of policy measures at all spatial scales. Based on such a risk assessment of Europe's regions, the EC's Structural Funds could be used for risk management, by using criteria relevant to risk and vulnerability to identify a region as eligible to funding through the Structural Fund objectives. The Integrated Risk Assessment of Multi-Hazards consists of four components (Fig. 2): Hazard maps: For each spatially relevant hazard, a separate hazard map is produced that shows the regions in which this hazard occurs and the intensity of this hazard.

Integrated hazard map: The information on all individual hazards is integrated in one map showing for each region the combined overall hazards potential.

Vulnerability map: Information on the hazard exposure as well as coping capacity with regards to potential hazards is combined to create a map showing the overall vulnerability of each region.

Integrated risk map: The information from the integrated hazard map and the integrated vulnerability map are combined to produce a map that shows the integrated risk that each region is exposed to.

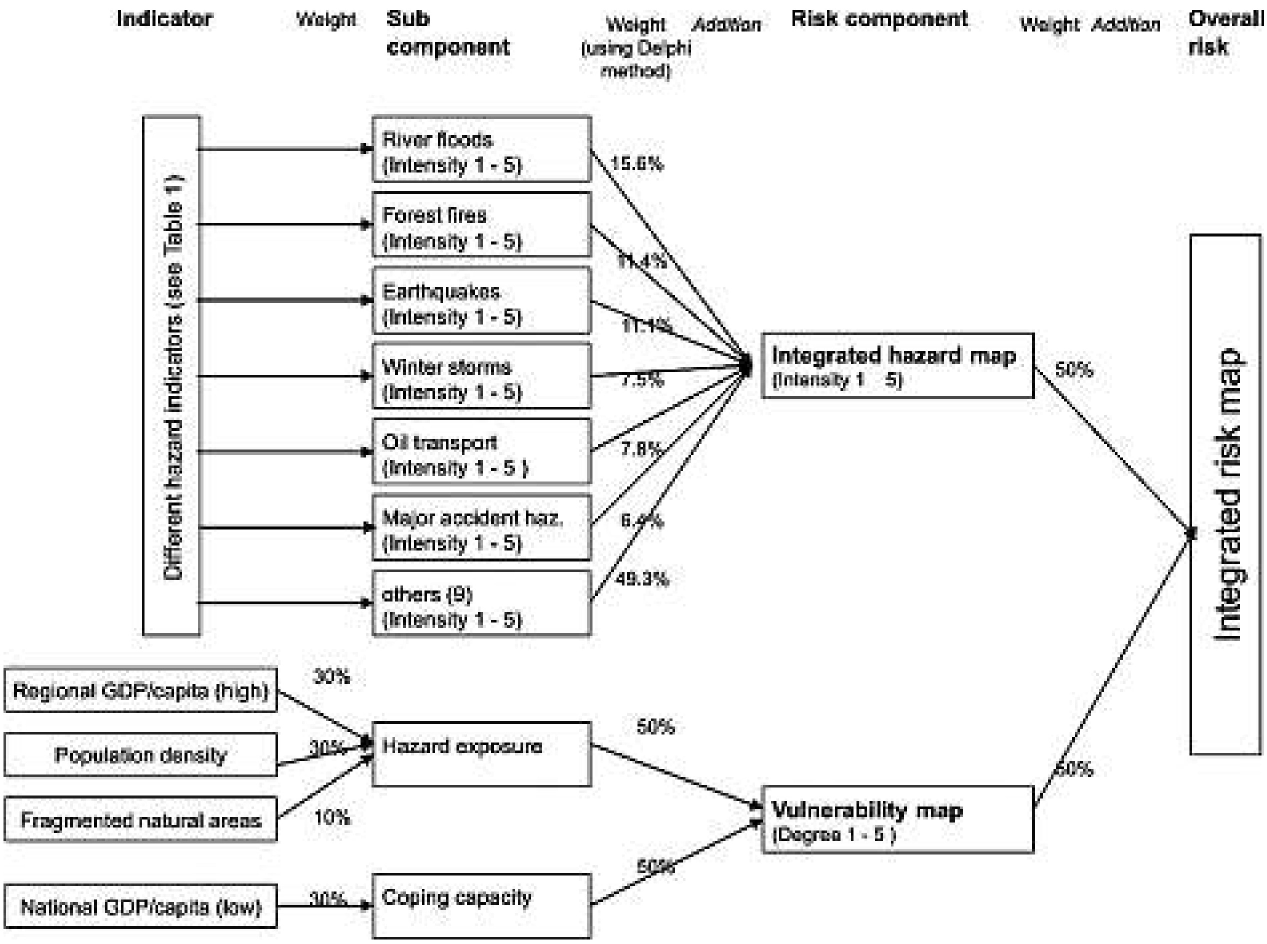

Fig. 2. Calculation of the Integrated Risk Index. In the following these main components of the approach are described in more detail.

3.2 Hazard Maps

Hazard maps only show where and with what intensity individual hazards occur, and they do not contain any information on regional vulnerability. Thus, these maps are merely hazard maps and not risk maps. The intensity of a hazard is determined on the basis of data on for example, a hazard's frequency and magnitude of occurrence. These differ due to the specific characteristics of each hazard, which makes it impossible to come up with one classification that is valid for all types of hazards. Therefore, the intensity of each hazard is classified separately on an ordinal scale using five relative hazard intensity classes (Table 1). This relative scale provides a way beyond the impasse despite the problem of the great, apparently insurmountable differences in assessing risks between the several scientific disciplines. This should be seen as one of the main problems that hinder an integrated risk assessment. In addition, this relative scale allows the use of different hazard related data regarding the several spatially relevant hazards.

3.3 Aggregated Hazard Map

Next, the individual hazard maps are aggregated to one integrated hazard map by means of the addition of the several single hazard intensities.[2] Mathematically, this is possible and easy to do because the intensities of all hazards were classified using five ordinal classes. When regarding seven hazards, the range of values therefore lies between 15 and 75 (15 hazards), which have to be converted to an overall hazard intensity of 1 to 5 (Table 1). More problematic is the question whether all hazards should be aggregated with equal or differing weights, that is, whether some hazards are more important than others. Such weighting of hazards implies normative decisions, which of course have a crucial impact on the results of the integrated hazard values. Different weighting schemes can be justified, depending on recent disaster experiences and thus heightened hazard perception. Therefore, the researchers involved and/or major stakeholders of the regions for which the risk assessment is conducted should engage in a so-called Delphi process to assign different weights to the hazards (see also chapter 10). The Delphi method, developed by Helmer (1966), has become widely accepted by a broad range of institutions, government departments, and policy research organisations (Turoff and Linstone 1975, Cooke 1991). The Delphi Method is based on a structured process for collecting and synthesizing knowledge from a group of experts through iterative and anonymous investigation of opinions by means of questionnaires accompanied by controlled opinion feedback. After several rounds of assigning weights, the individual scores are finally aggregated to achieve collective weights for all hazards. On this basis, the integration of all hazards and the production of an integrated hazard map can easily be performed. For that purpose, the single range of hazard intensity (1–5) will be multiplied with the Delphi weighting of a certain hazard.

3.4 Vulnerability Map

Another major component of a risk assessment is the assessment of a region's vulnerability to hazards (Fig. 2). The former reflects the hazard exposure of an area (infrastructure, industrial facilities and production capacity, residential buildings as defined by the regional GDP per capita) and the human damage potential (defined by the area's population density). Finally, the fragmentation of natural areas is used as an indicator for possible impacts on the ecosystem, since they are likely to be totally destroyed if a hazard strikes.

In contrast, coping capacity reflects on the response potential of an area's population. The coping capacity of an area is defined by its population den-

[2] A plausibility test (multiplication instead of addition) has shown the stability of the results: the ranking of the different regions is nearly the same.

sity and the financial, socio-cultural and institutional capacity to cope with a disaster. For pragmatic reasons, the latter is expressed by the national GDP per capita, because if a disaster occurs it is usually the nation state and the national economic capacity that are called upon to cope with the consequences of a disaster.

These indicators are used to measure vulnerability at the European level and they are not necessarily applicable on the regional level. For an application on a regional level, appropriate indicators should be used according to the region in question (see also Kumpulainen, S. in this volume).

As depicted in Fig. 2, these components of vulnerability need to be aggregated to create an integrated vulnerability index. Instead of weighting all components equally, a weighting of the three main components of 30% each (and the ecological vulnerability with 10%) seems to be more fitting, according to the judgement of the international research team that applied the approach on a European level. However, this weighting has to be understood as a normative decision and could easily be determined differently.

Finally, each vulnerability component is classified using five ordinal classes, thus facilitating the integration of the economic and social vulnerability to one integrated vulnerability index.

3.5 Aggregated Risk Map

Finally the vulnerability and hazard indices are combined. The new integrated risk index allows one to distinguish between those regions that are only hazardous and those that are risky, like those that also have a high degree of vulnerability. This methodology is derived from ecological risk analysis used in environmental impact assessments (Bachfischer 1978, Scholles 1997).

For the task of combining vulnerability and hazard potential, a 5x5 matrix is used (Table 1). The values of a region's hazard intensity and degree of vulnerability are summed up to yield the region's integrated risk value. This aggregation procedure yields nine risk classes.

As seen in the matrix, regions in one risk class may have the same overall risk value but the composition of their risks may be quite different. However, while the matrix above aims at an illustration of the basic methodological principles, the application in the ESPON hazards project is bit more complex. To distinguish between a higher intensity of a hazard or a higher degree of vulnerability, different shades of the same colour have been used. For example, risk class six may be reached due to high vulnerability or due to high hazard intensity, or because of medium values for both items. After determining the risk class for each region under study, an integrated risk map is produced using the same colours as in the risk matrix.

Table 1. Integrated risk matrix.

Degree of Vulnerability Overall Hazard Intensity					
1	**2**	**3**	**4**	**5**	**6**
2	**3**	**4**	**5**	**6**	**7**
3	**4**	**5**	**6**	**7**	**8**
4	**5**	**6**	**7**	**8**	**9**
5	**6**	**7**	**8**	**9**	**10**

4 OPEN QUESTIONS AND LIMITATIONS

While this aggregation procedure has the advantage of being transparent and easy to perform, it does not, however, take into account the interrelations between hazards (exacerbating or ameliorating effects). Unfortunately, very little scientific work has been done so far on such cross-hazards effects, let alone on assessment methods that would integrate such effects. The composition of an integrated risk index based on relative hazard intensities can be seen as a way beyond the impasse of different scientific approaches under the acceptance of some methodological problems. The following points have to be discussed in this context:

Weighting problem: The Delphi method was presented to weigh hazards and vulnerability indicators on a regional level. Although precautions were taken to avoid such influence, events occurring during the inquiry can impact the attitude of participants (e. g. the southeast Asia Tsunami in December 2004). Nevertheless, the occurred deviation from the low estimation of this hazard (only 1.4%) cannot be interpreted as distortion only. Accepting that the panel is dealing with uncertainty, each event also generates knowledge and is an impulse for reconsideration in the light of the knowledge. Thus, weighting results generated by the Delphi method may be seen as snap-shots and therefore need regular update.

Changes in parameters can shape risk in the future. The index presented in this paper and used in the ESPON hazards project is based only on past data. However, to acknowledge such changes, a dynamic component, that aims at monitoring these parameters (changes in population density and GDP/capita and changes in hazard intensity) has to be integrated in the monitoring of spatially relevant trends.

Problem of data quality: When applying the methodology, one will find that data from concerned hazards often differs quite largely from each other. For some hazards, only the number of historic hazardous events will be available, while for other hazards one will find detailed loss data. On a general methodological level, this means a low comparability of the hazard intensities. On a practical level, however, the presented methodology also shows a way out of this problem by transferring all data on hazard intensities into a relative scale. An ideal set of data would consist of reliable information about probable annual losses (PAL; for frequent hazardous events) and probable maximum losses (PML; for very unlikely events). Limits of measurability: Especially in the field of coping capacity, the search for appropriate indicators and data will soon show the limits of measurability. As the methodology only accepts quantitative data, other nonquantitative aspects that may be very important for a community's coping capacity (like social cohesion, organisational structures) cannot be included in this model.

Problem of fit: This describes the problem of congruence or compatibility between hazard zones and institutional arrangements that are created to manage risks (Young 2002). The more punctual or linear typical hazard zones are, the more inexact the result for the whole area will be because administrative borders in general are not congruent with the boundaries of hazard zones.

5 OUTLOOK

Generally, the described methodology can be characterised as very flexible in terms of spatial scale as well as the data sets and indicators to be used as analytic bases for assessing hazard intensity and degree of vulnerability. The methodology is easily understandable and leads to illustrative, and graphically visible results. Concerning the weighting of the different hazards, the use of the Delphi method offers a good possibility for an acceptable multi-risk assessment in situations of incomplete or incomparable data sets. In addition, it is possible "to play" with different weightings to approve the plausibility of the results. Moreover, proper attention can be paid to normative based estimations concerning the importance of the different vulnerability indicators.

The presented application of this methodology aims at an inter-regional comparison of regions at risk. This would be good basis for a reorientation of EU-funding policy. However, with regard to a potential use of the presented approach for regional planning or preparatory land-use planning, a more detailed hazard and vulnerability assessment is needed for decision-making regarding tolerating or altering risks. Thus, a weighing-up seems to be possible that carefully considers the appropriate level of protection in view of the different damage potentials (considering values such as residential areas, industrial facilities or transport infrastructure). Thus, concrete designations within a regional plan or a preparatory land-use plan could be made. In this context, the current European research project “ARMONIA” (Applied Multi Risk Mapping of Natural Hazards for Impact Assessment”, www.armonia.net) should be mentioned. The author of this paper is, among others, responsible for a comparison in dealing with natural hazards in regional and local land-use planning in the different member states of the EU.

Concerning vulnerability assessment as a whole, more attention should be paid to institutional vulnerability (see e. g. ECLAC/ IDB 2000). Political and institutional vulnerability, understood as institutional weakness as a whole, and more specifically, the weakness of the democratic system, has often been seen as one of the major causes of vulnerability with regards to natural phenomena. The weakness of the democratic system has negative consequences for the efficiency of public policies, the legitimacy of government action, participation by citizens and the private sector in national efforts. There is a close relationship between the need to reduce vulnerability and the increase in the organizational and participatory capacity of communities, the private sector and government.

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SPATIAL PATTERN OF HAZARDS AND HAZARD INTERACTIONS IN EUROPE

by
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Tarvainen. T., Jarva, J. & Greiving, S. 2006. Spatial pattern of hazards and hazard interactions in Europe. Natural and technological hazards and risks affecting the spatial development of European regions. *Geological Survey of Finland, Special Paper 42,* 83–91, 2 tables, 3 maps.

The ESPON Hazards project developed a typology of regions that clusters NUTS 3 areas in Europe that are threatened by similar hazards. The first step of this hazard-based typology aims at identifying given hazard interactions based on real physical processes from casual correlation. For the elaboration of the hazard typology of regions, interactions are only considered when the hazard intensities in a certain region are above average. The developed European wide hazard interaction map sums up the number of identified interacting hazards per NUTS 3 region to indicate the existing additional cumulative effects of hazard interactions in space. Several hazard combinations on European scale were also studied, and the distribution of selected hazard types was compared with existing geographical and normative regions in Europe.

This kind of analysis of hazard interactions is useful and even an indispensable tool for a multi-hazard approach. The analysis of existing hazard clusters might also be helpful for an adapted funding strategy in the different INTERREG regions in view of the given differences in the hazard pattern. This kind of hazard interaction analysis (on a more detailed spatial scale) could also be part of the forthcoming directive on hazard mapping, to be considered in regional as well as local land-use planning. In this context, the Strategic Environment Assessment (SEA) Directive (2001/42/EC) offers an already existing procedural framework to assess natural and technological hazards in spatial planning.

Key words: natural hazards, technological hazards, spatial distribution, cluster analysis, spatial planning, Europe

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1 HAZARD BASED TYPOLOGY OF REGIONS

An important result of the ESPON Hazards project is the development of a typology of regions that clusters areas in Europe that are threatened by similar hazards in space and mostly in time, too. This typology does not consider the aspect of vulnerability and therefore, it is a hazard-based typology compared to a risk-based typology. This is due to the fact, that, according to the chosen methodology, there are no differences in vulnerability regarding the different hazards on a European-wide level. Hazard-based typology also does not consider the different weighting of hazards.

1.1 Development of the hazard interactions map

The first step of hazard-based typology aims at the identification of given hazard interactions, based on real physical processes from casual correlation. This task could be carried out with a plausibility test. For that purpose, the following list of given interactions (see Table 1), based on a literature research, have been elaborated upon. This list summarises the interactions of fifteen different hazards, investigated in the ESPON Hazards project, in a matrix, according to the following scheme:

1 = Existing influence of a hazard on the other hazard,
0 = No physical influence of a hazard on the other hazard.

In the case of existing vice versa interactions (e. g. earthquakes – volcanic eruptions), the interaction will be counted twice. This means that in areas threatened by earthquakes and volcanic eruptions, both interaction values are considered. Due to the regional overview character of the ESPON 2006 Programme approach, single spot hazard combinations could not be taken into account, like landslides and nuclear power plants.

The most interesting result is the dominance of geological hazards (earthquakes and volcanic eruptions) as a cause of influences on other hazards. This means that the agglomeration areas within seismic or volcanic active zones can be identified as heavily threatened by a wide range of hazard interactions. However, technological hazards are the most sensitive hazards to the influence of other hazards.

For the elaboration of the hazard typology of regions, interactions are only considered when the hazard intensities in a certain region are above average (i.e. hazard intensity classes are IV and V, when the overall classification for the hazard intensity is from I to V, see Greiring, S. in this volume for a more detailed description of the methodological approach). Otherwise, it would be impossible to identify specific correlations due to the fact that almost every region, on a moderate level, is more or less threatened by certain hazards, like earthquakes or major accident hazards.

The following matrix in Table 2 gives an example of the specific occurrence of hazards in the regions by showing the hazard intensity classes for different hazards. Table 2 shows, for example, that regions A and C are characterised by the hazard interaction “flood-storms-chemical plants”, and for example, hazard intensity for these hazards is IV or V.

There is obviously an additional hazard potential in view of a possible coincidence of different hazards in space and time (if a river flood and at the same time a storm surge would occur, this is the worst case scenario for the Rhine or Elbe estuary).

A hazard interaction map sums up the number of identified interacting hazards per region (in five classes) to indicate the existing additional cumulative effects of hazard interactions in space. This means that a certain region with high classes of IV or V in hazard interaction map indicates a large amount as well as a greater probability and magnitude of consequences of hazard interactions. This analysis could be integrated in any decision about toleration or altering risks in this region.

However, the physical processes as well as the unforeseeable social and political implications could be very complicated in cases of an interaction between different hazards in space and time. As a result, the aggregated hazard map was not changed due to identified hazard interactions.

Table 1. Selected hazards and hazard influences.

Causer (x-axe) / Result (y-axe)		Avalanches	Droughts	Earthquakes	Extreme temperatures	Floods	Forest fires	Landslides	Storm surges	Tsunamis	Volcanic eruptions	Winter Storms	Air traffic hazards	Chemical plants	Nuclear power plants	Oil processing, transport & storage	Sum (most sensitive hazards to other hazards)
Natural hazards	**Avalanches**	X	0	1	1	1	0	0	0	0	1	1	0	0	0	0	**5**
	Droughts	0	X	0	1	0	0	0	0	0	0	0	0	0	0	0	**1**
	Earthquakes	0	0	X	0	0	0	0	0	0	1	0	0	0	0	0	**1**
	Extreme temperature	0	0	0	X	0	0	0	0	0	1	0	0	0	0	0	**1**
	Floods	0	0	0	0	X	0	0	1	0	1	1	0	0	0	0	**3**
	Forest Fires	0	1	0	1	0	X	0	0	0	1	0	1	1	1	1	**7**
	Landslides	0	0	1	0	0	0	X	1	0	1	0	0	0	1	0	**4**
	Storm Surges	0	0	0	0	0	0	0	X	0	0	1	0	0	0	0	**1**
	Tsunamis	0	0	1	0	0	0	1	0	X	1	0	0	0	0	0	**3**
	Volcanic Eruptions	0	0	1	0	0	0	0	0	0	X	0	0	0	0	0	**1**
	Winter Storms	0	0	0	0	0	0	0	0	0	0	X	0	0	0	0	**0**
Technological Hazards	**Air traffic hazards**	0	0	0	0	0	0	0	0	0	1	1	X	0	0	0	**2**
	Chemical plants	0	0	1	0	1	1	0	1	1	1	0	1	X	1	1	**9**
	Nuclear Power Plants	0	0	1	0	1	1	0	1	1	1	0	1	1	X	1	**9**
	Oil processing, etc	1	0	1	0	1	1	1	1	1	1	1	1	1	1	X	**12**
Sum (most influencing hazards on other hazards)		**1**	**1**	**7**	**3**	**4**	**3**	**2**	**5**	**3**	**11**	**5**	**4**	**3**	**3**	**3**	

Table 2. Matrix for the identification of regional hazard typologies.

Type of hazard/NUTS 3 region	Region A	Region B	Region C	Region D	…
Flood	IV	II	IV	I	
Storms	IV	III	V	III	
Chemical plants	V	I	IV	II	
…					

1.2 The hazard interactions map

The hazard interactions map is based on the calculation method described above for possible combinations of hazards shown in Table 1. Altogether, 59 hazard combinations were studied for all NUTS 3 areas. The overall hazard interaction map is presented in Map 1. The map shows the number of hazard combinations in each NUTS 3 area. Eight of these physically possible combinations did not occur in any European NUTS 3 region. For example, the combination of high volcanic eruption risk and high risk for large river floods was not identified for any region.

The most common hazard combination was major river floods – landslides: hazard intensity of these two hazards was high in 146 European NUTS 3 areas (See Map 2). Other common hazard combinations include: winter storms – storm surges (103 NUTS 3 areas); hazards from chemical production plants – hazards from nuclear power plants (89 NUTS 3 areas); droughts – forest fires (74 NUTS 3 areas); storm surges – landslides (52 NUTS 3 areas); storm surges – hazards from nuclear power plants (41 NUTS 3 areas); earthquakes – landslides (33 NUTS 3 areas); and tsunamis – landslides (33 NUTS 3 areas).

Storm surges and large river floods can potentially lead to problems of power production in nuclear power plants if the intake of clean cooling water is flooded (Mai et al. 2002). This nearly occurred during the winter storm in January, 2005 in the nuclear power plant in Loviisa, Finland when the water level arose 171 cm above normal (STUK, 2005). A potentially elevated hazard combination of floods and nuclear power plants is found in 105 NUTS 3 areas. However, it should be pointed out that the data on hazards from nuclear power plants does not illustrate the exact location of nuclear power plant, but NUTS 3 areas that fall into a 30 km radius from the plant.

2 HAZARD CLUSTERS

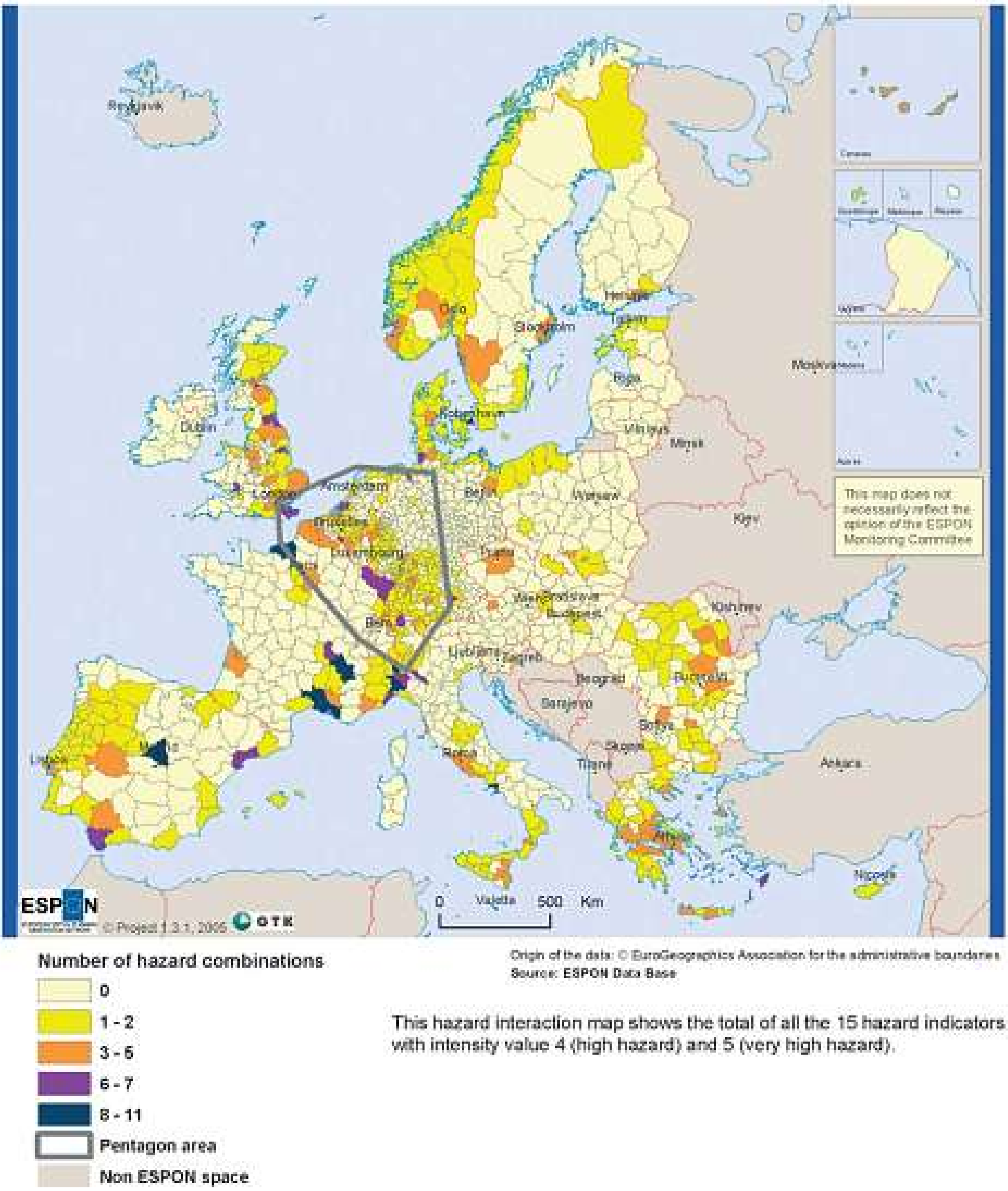
In addition to the development of the overall hazards interaction map, several hazard combinations were studied on a European scale, and the distribution of selected hazard types were compared with existing geographical and normative regions in Europe.

Main clusters, which could be the basis for special policy recommendations and spatial planning response were:

- Coastal areas, threatened by storm surges/winter storms and floods (mainly in north-western Europe)
- Alpine-areas, threatened by avalanches/landslides and floods
- Mediterranean areas, threatened by forest fires and droughts
- River valleys, threatened by river floods and often technological hazards due to the given concentrations of infrastructure
- Areas that are located above tectonic active zones, threatened by volcanic eruptions and earthquakes, tsunamis and landslides
- The Pentagon Area (cluster of technological hazards) developed by the ESPON 1.1.1 project "Potentials of Polycentric Development in Europe" see http://www.espon.lu/online/documentation/projects/thematic/index.html
- The INTERREG IIIB regions.

The main clusters were compared with the hazard interactions maps. Certain patterns of hazards and European regions could be identified, for example, coastal areas in north-western Europe are affected by winter storms and storm surges, see Map 3.

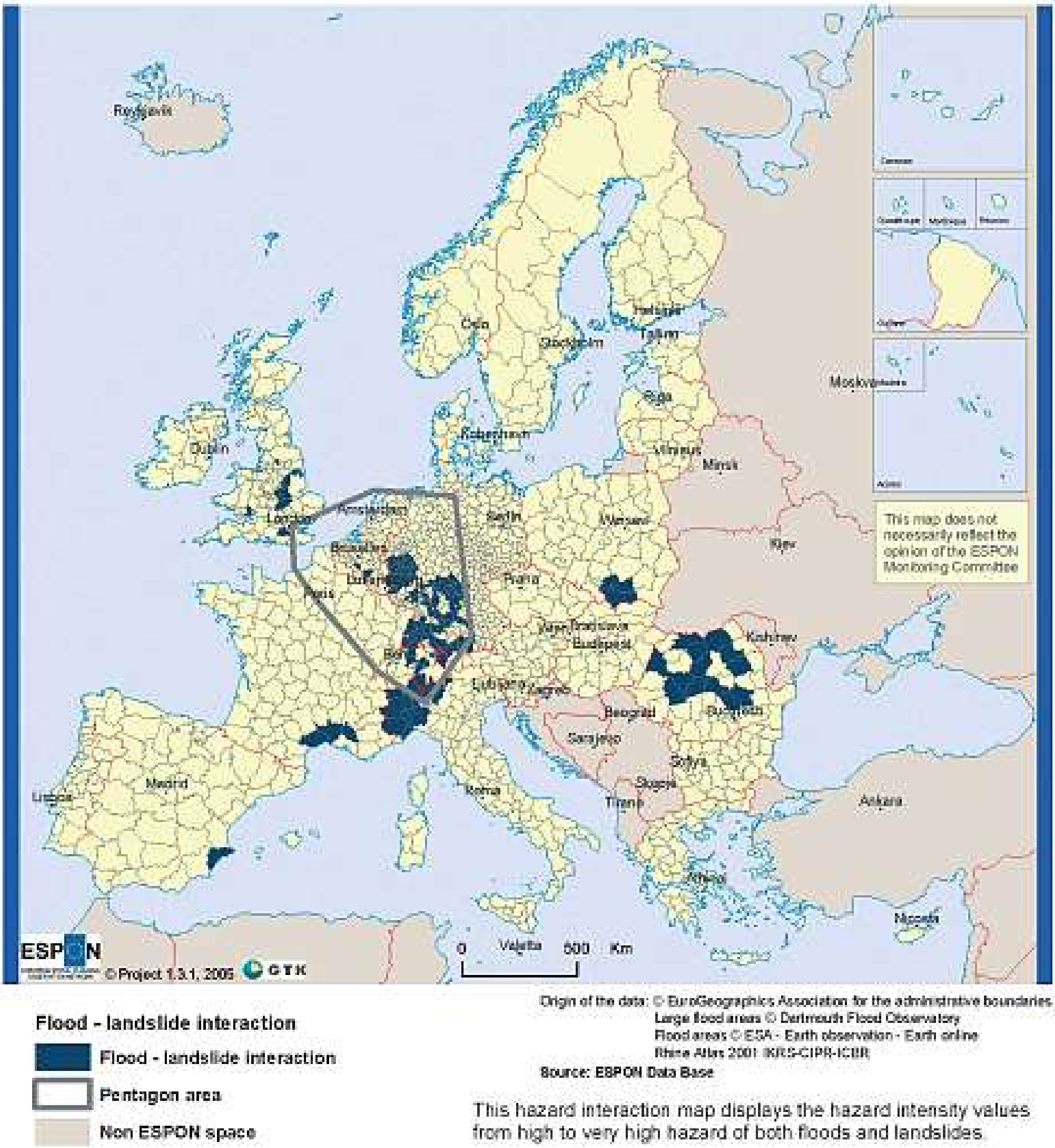
Alpine areas are expected to be threatened by landslides, avalanches and floods. Combinations of floods and landslides were common in the western Alpine region, but similar combinations are found also in many regions in the Schwarzwald area in southern Germany, in the Ardennes in France, in the river Rhône Valley between the Cevennes and the French Alps, as well as in the Carpathian Mountains in Romania. The majority of the flood-landslide combinations (107 out of 146) were located inside



Map 1. Hazard interactions map shows the number of hazard combinations in each NUTS 3 area. Map production Hilkka Kallio, GTK.

the Pentagon Area. Avalanches are typical for the Alpine region, but they were not combined with landslides or floods, as single spot data are difficult to combine on NUTS 3 level maps.

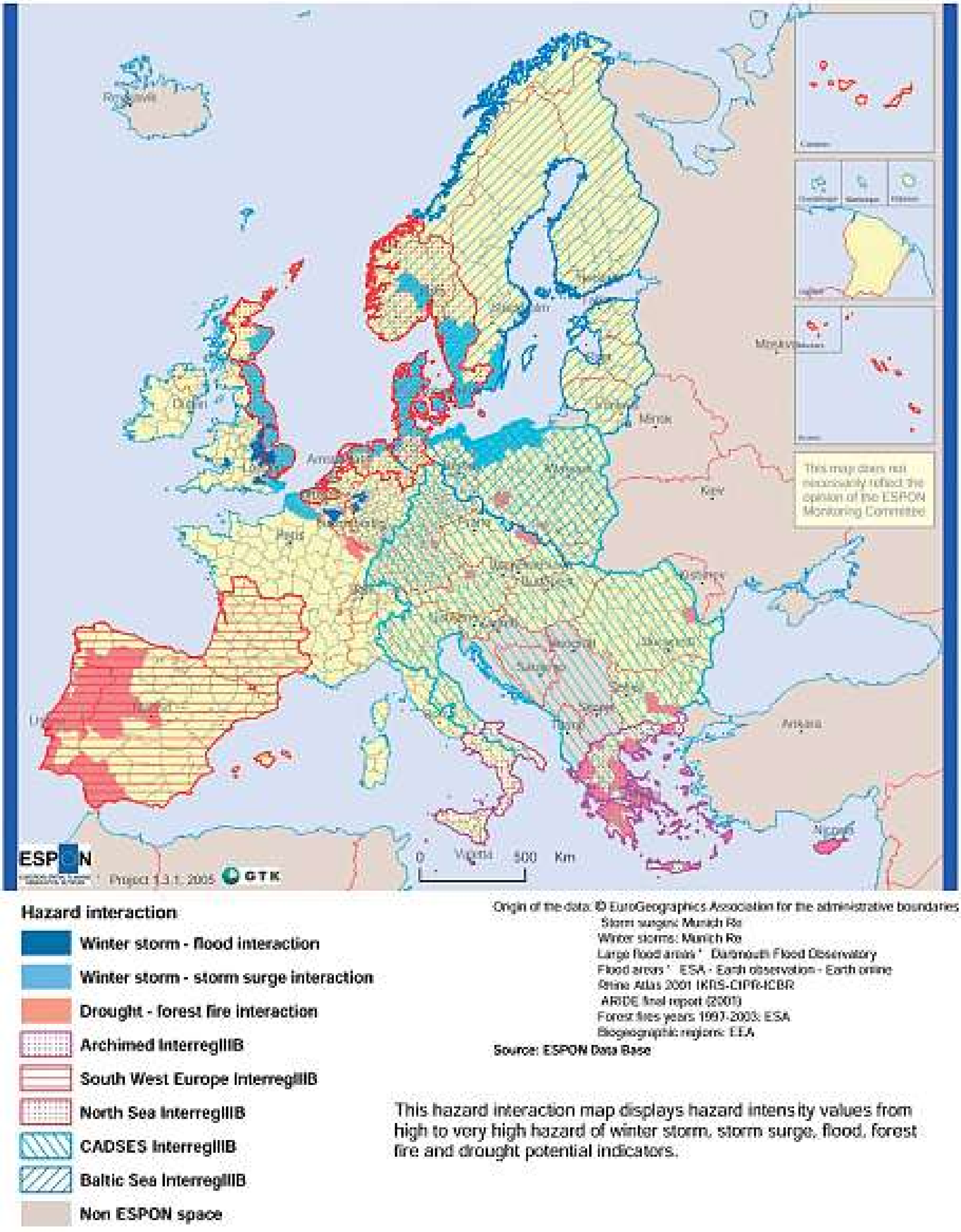
Mediterranean areas have moderate to very high (III – V) hazard intensity for forest fires. The methodology chosen, however, only takes into account hazard intensity classes IV and V (high and very high). The combination of drought potential and forest fire was most common in Portugal, where 22 NUTS 3 regions out of 30 have this kind of hazard combination. Also, in Spain, Greece and Cyprus the combination of droughts and forest fires is commonly found, see Map 3.



Map 2. The most common hazard combination: Flood and landslide interaction. Map production Hilkka Kallio, GTK.

Floods and technological hazards are assumed to threaten river valleys. Many of the major European river basins have high flood hazard intensities. The combination of a high flood hazard and hazards from chemical production plants was identified in 41 NUTS 3 regions. These regions are located in the western part of the river Po Valley in Italy and in Germany around some big industrial areas near Düsseldorf, Stuttgart and München. More of these hazard combinations can be found around Northamptonshire and some other industrial areas in the United Kingdom and in Belgium (south of Brussels near the city of Namur). High flood hazard intensity combined with hazards from oil production was found only in five areas in France and Italy. High flood intensity and nuclear power plant hazards were combined in 105 NUTS 3 areas in France, Italy, Germany, Belgium and the United Kingdom.

Tectonically active zones could have a combination of volcanic eruption hazards. However, the com-



Map 3. Distribution of three hazard interactions (winter storm - flood; winter storm - storm surge and drought - forest fire) in selected Interreg IIIB regions. Map production Hilkka Kallio, GTK.

bination of volcanic eruption hazards and earthquakes was identified in only two NUTS 3 regions: The Dodecanese islands in Greece and Guadeloupe island (overseas territories).

In the view of the oil pollution hazard in coastal areas, the interaction of storms and hazard from oil production was studied. The interaction was found in 19 NUTS 3 areas from which 9 NUTS 3 areas are situated onshore in Norway, Denmark, Germany, the Netherlands, France and United Kingdom.

The Pentagon Area shows a strong cluster of technological hazards, as for example, more than 50% of the regions that have more chemical production plants than average (total 215 NUTS 3 areas) are found here. The largest number of regions with a higher density of chemical plants than average outside the Pentagon Area is found in the United Kingdom. The rest of the areas of dense chemical production are scattered all over Europe.

The cluster of the most important technological hazards was also calculated. Hazards from chemical plants, oil production and nuclear power plants were, however, found only in six NUTS 3 areas located in France and northern Italy.

3 HAZARD PATTERNS AND CLUSTERS IN INTERREG IIIB REGIONS

Several Interreg IIIB regions (for more information on the Interreg regions, please see http://europa.eu.int/comm/regional_policy/interreg3/abc/voletb_en.htm) show correlations with certain hazard patterns. For example, the North West Europe Region has an elevated hazard from chemical production plants. The South West Europe Region has a strong accumulation of forest fires and droughts, while the Western Mediterranean Region and the Archimed Region have elevated forest fire and tsunami hazards. The entire North Sea Region and parts of the Baltic Sea Region have a strong accumulation of winter storm hazard.

The hazard interaction maps were also compared with the existing Interreg IIIB regions. Some of the Interreg IIIB regions show a strong correlation with certain hazard interactions. The North Sea Region is characterized by winter storms and storm surge hazards, continuing into the southern part of the Baltic Sea Region. The combination of earthquakes and landslides is elevated in the southern part of the Interreg IIIB CADSES Region (Central, Adriatic Danubian and South-East Europe). The combination of a precipitation deficit as a drought indicator and forest fires are found in the Interreg IIIB Regions South West Europe, ARCHIMED and CADSES, as shown in Map 3.

4 THE STRATEGIC ENVIRONMENT ASSESSMENT (SEA)

The European wide interaction maps presented in this article could be a basis for a forthcoming directive on hazard mapping to be considered in regional as well as local land-use planning. The maps should be on a more detailed spatial scale when using them in local level planning. The SEA Directive offers an already existing procedural framework to assess natural and technological hazards in spatial planning.

The purpose of the SEA Directive is to ensure that environmental consequences of certain plans and programmes are identified and assessed during their preparation and before their adoption. SEA will contribute to more transparent planning by involving the public and by integrating environmental considerations. This will help to achieve the goal of sustainable development. (European Commission, 2005)

The key task of the SEA is in accordance with Art. 3 EU directive 2001/42/EC the assessment of the *"significant effects on the environment, including on issues such as biodiversity, population, human health, fauna, flora, soil, water, air, climatic factors, material assets, cultural heritage including architectural and archaeological heritage, landscape and the interrelationship between the above factors"* (European Union 2001, Annex 1, Letter f). The results of this assessment, summarised in the environmental report, have to be taken into account in decision-making about specific plans or programs (European Union 2001, Art. 2b and 2c).

Annex II of the directive, which points out the characteristics of the effects and the area likely to be affected, indicates the following risk-related aspects as relevant for the assessment of significant effects on the environment:

– the probability, duration, frequency and reversibility of the effects,
– the cumulative nature of the effects,

- the trans-boundary nature of the effects,
- the risks to human health or the environment (e.g. due to accidents),
- the magnitude and spatial extent of the effects,
- the value and vulnerability of the area likely to be affected due to intensive land use for example
- the effects on areas or landscapes which have a recognised national, community or international protection status

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INFLUENCE OF CLIMATE CHANGE ON NATURAL HAZARDS IN EUROPE

by
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Future climate change may affect both the frequency and intensity of natural hazards. To quantify these expected changes, indices of climate extremes derived from output from scenario simulations using high-resolution regional climate models can be analysed. Results based on some indices related to temperature and precipitation are presented in this study. Regional climate model data from the Prudence database are used. The results show a future with substantially milder winter cold extremes and a 5–8°C warming during warm extremes for large parts of Europe. Furthermore, the results indicate an intensification of heavy precipitation and an increase in dry spells in most of Europe. Climate extremes are rare and interact with other more local factors, thus each single event tends to have a unique character. The impact on society depends on multiple factors such as the sequence of events and their timing as well as the ability of the society to adapt and prepare. The decision-makers awareness and perception of climate change is thus important.

Keywords: natural hazards, climate change, climate effects, temperature, atmospheric precipitation, floods, drought, Europe

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1 INTRODUCTION

Observed climate extremes

The emerging awareness of the ongoing climate change (Houghton et al. 2001) and the proposition that extreme weather events (climate extremes) may become more frequent and/or more intense extremes in Europe (Kundzewicz et al. 2001) has sparked a public debate in the media whether apparent changes to the frequency of natural disasters are signs of this climate change. In particular, this debate has been fuelled by recent devastating natural disasters in Europe, for example:

- The January 1987 cold wave over large parts of Europe;
- Several winter windstorms over the British Isles and northern Europe in 1989–1990;
- The 1997 summer Vistula/Odra flood in central Europe;
- Several winters windstorms over western Europe and southern Scandinavia in 1999–2000;
- The 2002 summer Elbe flood in Germany;
- The 2003 summer heat wave over France and drought in Italy;
- The January 2005 windstorm over northern Europe.

These examples are just some of the worst and geographically most extensive natural disasters during recent decades, where each one resulted in loss of human life, ruined human well-being, and caused severe disruption to basic societal services and substantial economical losses.

On a large scale, the gradually increasing temperature in combination with *winter mild spells* increases the risk for slope instability (permafrost melting and/or wet soils/precipitation) and eventually landslides, and *windstorms* can be devastating to forests and society. In coastal areas, *storm surges* aggravate the damage from windstorms. Extreme temperatures, both short-lived extremes and longer spells increase human discomfort and constitute a health hazard. Even if the meteorological condition causing a natural hazard is a large-scale phenomenon, the actual destruction is usually very unevenly distributed because of a complex interaction with the local physiography, land cover and distribution of population and property.

On a more regional and local scale, extreme weather events regularly have a significant impact, although the overall impact on a national or European level is less prominent. For example, *intensive rainfall* creates local flash floods and overflowing urban drainage systems; *hailstorms* destroy crops and may also occasionally cause considerable damage to property; *heavy snowfall* disrupts communications and may, in severe cases, cause substantial damage to forests; and *tornadoes* bring local havoc to nature and property (cf. Table 1). All these local weather extremes are associated with sharp temperature and moisture gradients in the atmosphere.

There are other natural hazards that are driven by a more complex combination of weather conditions and other factors, like *avalanches* that require a specific snowpack structure and temperature conditions in combination with an initiating disturbance/impact/vibration, and *wild fires* that become a major problem under dry spells, high temperature and windy conditions in combination with the presence of combustible material and a natural or human-made igniting incident.

The subject of *drought* and *water scarcity* is even more complex and in addition to the previous factors, involves factors related to water demand, societal vulnerability and coping capacity, as well as expectations. In fact, Estrela et al. (2001, p.8) noted that “*Although drought is a phenomenon that is apparently easy to recognise, there is no general agreement regarding its definition”*. Therefore, “droughts” are often divided into different categories depending on how it is quantified and what impact it has. The following categories are commonly used; meteorological drought (precipitation deficit), hydrological drought (deficit in runoff, streamflow, and sometimes groundwater availability), agricultural drought (water scarcity in relation to common agricultural practices in a region), socio-economic drought (water scarcity in relation to what is expected/demanded by society). The first two are comparatively easy to quantify in relation to measurable meteorological and hydrological factors, the latter two further includes the societal expectations that may shift over time, thus changing the vulnerability of society. Hisdal and Tallaksen (2000) provided a comprehensive discussion of the background and issues involved in applying these drought categories to European conditions.

Compilations of damage reports suggest that losses from floods (e.g. Mitchell 2003; Kundzewicz and Schellnhuber 2004) and windstorms (e.g. Schelhaas et al. 2003; Nilsson et al. 2004; Leckebusch and Ulbrich 2004) have increased significantly during recent decades. The EEA report (EEA, 2004) draws

Table 1. Overview of natural hazards capable of causing catastrophic societal impact and the main underlying climatic factor that affects the hazard intensity. Also listed are other factors that may contribute toward a change in the overall risk of a catastrophic impact.

Natural hazard	*Climatic factor*	*Other factors**
Storm surges (coastal flooding)	Low pressure Windstorm Sea-level rise	Geographical distribution Societal sensitivity
Flooding (inundation)	Excessive rainfall for an extended period, possibly in combination with snowmelt and/or high sea-levels	Geographical distribution Land-useSocietal sensitivity
Flash floodsHeavy rainfall	Convective precipitation	Geographical distribution Land-use Societal sensitivity
Hailstorms	Convective precipitation	Societal sensitivity Land use
Landslides	Saturated soils (wet spells/ heavy precipitation) Thawing of mountain permafrost	Geographical distribution
Avalanches	Snowpack structure temperature evolution/ precipitation	Geographical distribution
Drought	Precipitation	Geographical distribution
Water scarcity	Temperature/evaporation	Societal sensitivity Land use
Excessively hot day Heat wave	Temperature	Societal sensitivity
Excessively cold day Cold wave	Temperature	Societal sensitivity
Forest fires	Precipitation Temperature/evaporation Wind	Land use

* The terms are employed here in a tentative instrumental sense as follows:
"Societal sensitivity" is the sensitivity of the society at any specific place without fundamentally changing the land-use or human activities at that place (but including general societal development, that leads, for example, to a society becoming successively more sensitive to disruptions in power supply or transportation for example). Thus, it is related to the *coping capacity of the society*.

"Geographical distribution" denotes development of new activities at a place (for example construction accepted in a floodplain, along a low lying coast or on a steep slope) that are closely related to the *exposure*.

"Land use" are changes to land use practices without fundamentally changing the land use (for example, using more water-demanding crop varieties in agriculture, or introducing large clear cut forestry), thus being closely related to the coping capacity of the agricultural and forest production.

on numerous studies of a diverse set of climate change impact indicators. In doing so, the report provides a review of various possible climate impacts that already may be emerging. However, many of these climate indicators may also be sensitive to other environmental and societal changes that are taking place.

To isolate the influence of climate change from other environmental and societal influences, meteorological observations are the only stringent source of information. However, due to a lack of high quality long-term data (Easterling et al. 2000), major difficulties remain regarding variations and trends in climate extremes. However, at the instigation of several European and international projects, there is now a growing body of high-quality long-term datasets with high enough time-resolution to begin analysing climate extremes. Examples of such projects are WASA (Carretero et al. 1998), ADVICE (Jones et al. 1999), IMPROVE (Camuffo and Jones, 2002), and the EMULATE project (<http://www.cru.uea.ac.uk/projects/emulate>). In addition, with particular relevance to infrequently occurring climate extremes having catastrophic consequences (high-impact, low probability regional events), important information is being gained through historical climatology research, and Europe may be well positioned because of rich data sources in various archives (Brázdil et al. 2005).

With this still limited but slowly growing body of data, it is now possible to begin assessing recent extreme events. For example, the 2003 heat wave over southern Europe was identified as a unique event in a historic perspective and more resembling projected future conditions (Beniston 2004; Schär et al. 2004; Stott et al. 2004). Windstorms and associated hazards, on the other hand, are more problematic. The WASA project concluded (Carretero et al. 1998) that long-term wind observations are fraught with various problems that make them less trustworthy, and many observational analyses (e.g. Alexandersson et al. 2000; Bärring and von Storch 2004) conclude that up to now, there is no long-term change in the frequency of windstorms. In fact, there are currently signs of regionally opposing variations and trends. Nevertheless, most regional climate change scenarios indicate that northern Europe (the British Isles, North Sea, Scandiavia, Netherlands, northern Germany, and the Baltic region) may see a more vigorous storm climate in the future.

With the exception of the 2003 European heat wave, it has not been possible to attribute either single climate extreme events or perceived trends in climate extremes to ongoing climate change. Instead, concurrent changes to land use and societal sensitivity usually complicate, or even dominate the picture. For example, the increase of hurricane damages in southeastern United States has been shown to be an effect of increased societal sensitivity in combination with changed geographical distribution of built-up areas resulting in a dramatic increase of insured losses (Pielke and Landsea 1998). Similarly, increased forest damage due to windstorms during recent decades cannot be attributed to a change in storm frequency (Schelhaas et al. 2003; Nilsson et al. 2004; Schlyter et al. 2005). This entanglement of climate variability and societal change is not a new phenomenon (Stehr 1997; Stehr and von Storch 1995; von Storch and Stehr 2000), as seen by wind erosion on northern European agricultural lands (Bärring et al. 2003; Warren 2002).

Future climate extremes

Climate change has been a major topic in scientific and political considerations for almost two decades. There is now scientific consensus that the main driving force behind this climate change is the anthropogenic emission of greenhouse gases, with additional influence from anthropogenic aerosols, volcanoes, variation in solar output, as well as from internal variability within the climate system (Houghton et al. 2001). An estimate of the relative contribution of these different factors on global mean temperature has been obtained (Stott et al. 2000; Tett et al. 2002). However, on a regional scale, where the question of climate change appears more tangible, especially when considering extreme events, such an attribution to an anthropogenic climate change remains elusive. The often repeated statement is that extreme events may at least become more frequent (EEA 2004). This is straightforward when it comes to temperature extremes, where the link to the average temperature is fairly well established (Houghton et al. 2001), even though the relationship between changes in the mean and changes in extremes is probably non-linear (Kjellström et al. 2005).

For other variables, like wind or precipitation, the link between mean temperature change and extremes of these variables are more complex. First, the link between an increase in mean temperature and the mean of other variables may be non-linear. As well, the link between a change in the mean and in extremes of the variables is probably even more complex and in most cases not well understood. Nevertheless, McBean (2004) gave an outlook to possible extreme weather phenomena. He further pointed out that the probability of extreme events rises rapidly even in the mid-latitudes and thus in Europe. However, McCarthy et al. (2001) concluded that especially for Europe during the 20th century there was only a variance in the magnitude of extreme events but no clear trend can be registered.

It is important to stress that this paper discusses what might be denoted as climate extremes within a ‘moderate’ climatic response to the anthropogenic greenhouse gas emissions. That is, the focus is on how climate extremes (severe weather causing substantial impact on society and nature) may change given a change in the European mean temperature according to the IPCC projections (Giorgi and Hewitson 2001). We are not analysing what may happen in the event of any ‘climate surprises’ (like an extreme response from the climate system), such as a drastic change to the North Atlantic thermohaline circulation and other future scenarios of that sort. The reason being that such responses, although within what may happen to the climate system, are not well understood and are generally viewed as unlikely. As such, they are regarded as ‘high impact/low probability’ events.

Quantifying climate extremes

A future climate change can be expected to affect both the frequency and intensity of natural hazards and thus influence discussions on risk management of all climate-induced natural hazards. A common way to quantify the climate control of natural hazards is to analyse indices of climate extremes. These indices are constructed to measure the climate factor underlying a natural hazard. A large number of different but related indices of climate extremes exists in previously published analyses (e.g. Frich et al. 2002) and the European Climate Assessments (Klein Tank et al. 2002) has been used in several current European projects (e.g. MICE <http://www.cru.uea.ac.uk/projects/mice>, STARDEX <http://www.cru.uea.ac.uk/projects/stardex>), and it is usually not possible to designate one index as better or more appropriate than another index without focusing on a specific target application and/or geographic region.

Indices that all measure related aspects of a natural hazard do share a large proportion of variance. Selection of the detailed specification of any particular index is thus not critical for a general analysis of variations in the intensity of a natural hazard across a larger region, such as a large portion of Europe where natural hazards can result from slightly different climate extreme events.

2 DATA AND METHODS

Regional climate model data

Complex, physically-based climate models are needed to project future climate (Houghton et al. 2001). Although the understanding of climate processes and their incorporation in climate models has improved, they cannot yet simulate all aspects of climate. Uncertainties are particularly associated with clouds and their interaction with aerosols, shortwave radiation from the sun and longwave radiation from the Earth's surface. Confidence in the ability of these models to produce satisfactory projections of future climate has nevertheless increased substantially in recent years (Houghton et al. 2001).

As a result of this uncertainty, climate model simulation of future conditions should be regarded as a "*plausible, consistent, possible but not necessarily probable"* (*PCPnP*, von Storch 2004) suggestion for a future climate. This concept was introduced to underline that the output from any model run of future climates is just one out of many (innumerable) possible outputs.

For calculating the climate extreme indices, we used regional climate model data from the recently published Prudence database, <http://prudence.dmi.dk> (Christensen et al. 2005; Jacob et al. 2005). All in all, 13 different regional climate models were used in that project but here we use only model runs of the SRES A2 scenario (Nakiæenoviæ and Swart 2000), using the same forcing global coupled atmosphere-ocean model, the UK Meteorological Office, Hadley Centre HadCM3/HadAM3H model system. The regional climate models all have approximately the same spatial resolution, in this case about 50 km x 50 km or 2500km^2. To obtain robust results that are not influenced by any specific regional climate model, we form ensemble statistics across the different models and ensemble members.

Selected indices of climate extremes

In this study, we focussed on climate extreme indices related to temperature and precipitation. We thus covered the fundamental climate factors for several of the natural hazards listed in Table 1. The indices, defined in Table 2, cover both one-day extremes and longer spells. There are several reasons

Table 2. Summary of the indices of climatic extremes used in this study.

Index	Explanation	Relevant natural hazards	Fig.
Cold day (°C)	1st percentile of daily temperature	Excessively cold days	1
Cold wave (°C)	10th percentile of annual minimum 7-day temperature	Cold wave	1
Hot day (°C)	99th percentile of daily temperature	Excessively hot days	2
Heat wave (°C)	90th percentile of annual maximum 7-day temperature	Heat waveForest fire	2
Heavy precipitation(mm/day)	99th percentile of daily total precipitation amount for wet days (R>0.5 mm)	Heavy precipitationFlash floods Landslides	3
Wet spell(mm/7days)	90th percentile of annual maximum precipitation accumulated over 7 days	Flooding (inundation)	3
Dry spell(number of days)	90th percentile of length of the annually longest dry spell (R<0.5 mm)	DroughtWater scarcity Forest fire	4

for focusing on temperature and precipitation extremes.

First, from a climatological point of view, temperature and precipitation conditions are the most fundamental elements that define the climate of an area. An increasing mean temperature can be expected to result in substantial changes to temperature extremes. As well, according to basic physical principles an increasing temperature will intensify the hydrological cycle, thus bringing about changes to the precipitation climate.

From an impacts point of view, temperature extremes are well know to have a large impact on agricultural and forest production, and on public health. Similarly, both ends of precipitation extremes, floodings/flashfloods and dry spells/droughts, have substantial impact on society. However, while other climate extremes like windstorms and storm surges may cause severe impacts, their underlying physical processes are more complex and the climate projections are consequently more uncertain and less consistent.

Temperature conditions are represented by four indices. Two indices concern extreme temperature conditions during single days (*Hot day* and *Cold day*) and are calculated as the 99th percentile and 1st percentile of the daily mean temperature. That is, this temperature threshold is exceeded (for the 99th percentile in positive direction for hot days, and for the 1st percentile in negative direction for cold days) about 3–4 days per year. For even more extreme conditions, the change scales in an approximate linear way. By going further out into the extreme tails of the temperature distribution, the threshold becomes more and more susceptible to random variations and systematic biases in the models. Kjellström et al. (2005) validated a range of temperature percentiles of the models experiments used herein.

The other two temperature indices are designed to quantify heat waves and cold waves. They are calculated in two steps; first, the maximum (minimum) 7-day average temperature is calculated for each year. Second, the 90th percentile (10th percentile) of these annual maxima (minima) is calculated. In this way, the *Heat wave* (*Cold wave*) index characterises what may be exceeded once every ten years.

Three indices cover the key aspects of precipitation extremes. *Heavy precipitation* is the 99th percentile of wet days, where a wet day is defined as a day having at least 0.5 mm of precipitation. *Wet spell* is the 90th percentile of annual maximum precipitation total over any 7-day period. *Dry spell* is the 90th percentile of the annually longest period with precipitation below 0.5 mm. As the *dry spell* index is based on precipitation only, it effectively measures only the meteorological aspect of drought. Again, being based on the 90th percentile, these two spell indices quantify what, on average, will be exceeded roughly once every ten years.

The *Heavy precipitation* index quantifies one-day precipitation in each gridbox. It is related to flashfloods, soil erosion and slope stability. However, heavy precipitation occurs as highly localised showers affecting an area much smaller than a gridbox of 50x50 km^2. The seven-day wet spell index is relevant for flooding (inundation), where persistent precipitation first saturates the infiltration capacity of the soil and wetlands. The *dry spell* index is constructed slightly different. It is based on the annually longest dry period, which relies solely on precipitation. Without incorporating other factors, it is an index of meteorological drought because it measures dry spell lengths exceeded once in 10 years.

Conversion of climate model maps to the ESPON GIS system

The basic spatial units of the ESPON geographical database are the European NUTS 3 regions. The *Nomenclature of Territorial Units for Statistics (NUTS)* is, in practice, based primarily on the institutional divisions currently in force in the European member states (cf. <http://europa.eu.int/comm/eurostat/ramon/nuts/home_regions_en.html> for further details). The level 3 regions are defined as having between 150 000 and 800 000 inhabitants. With the very uneven population density existing across Europe, NUTS 3 regions are of widely different sizes. To integrate the climate model data with other types of spatial information, the approximately equal-area grid of the regional climate models has to be aggregated into irregularly shaped and variably sized NUTS 3 regions.

No robust conclusions can be based on only one model grid cell, but the full resolution maps lend themselves to spatial aggregation into regions that are homogeneous according to the map pattern rather than into regions that were predefined for other purposes and thus likely to cut the map pattern into heterogeneous units. For general climate information, this is less of a problem because of their generally smooth nature. However, for climate extremes such an aggregation becomes more complicated because of the spatially very local nature of some extremes in combination with their increased sensitivity to local physiographical factors. These physiographical factors are included into the regional climate models and are thus intrinsically included into the spatial pattern of the model output.

There is presently no well-established methodology for aggregating climate extremes into regions that are climatologically heterogeneous. For the purpose of this study, we therefore choose to focus on basic and well-known statistical measures (median, percentile level, or minimum or maximum, etc) of the grid cells belonging to a NUTS 3 region.

In line with the overall ESPON/Hazards methodology, the calculated index values were also transformed into ranks before introduced into the database. For all indices, with the exception of *Heavy precipitation* and *Wet Spell*, this was done by linearly dividing the interval spanned by index into six bins of equal size.

For the *Heavy precipitation* and *Wet Spell* indices, logarithmic intervals were used. This follows standard practice for precipitation amounts having a skewed distribution, and allows for comparison across widely different precipitation regimes (as well as changes across different regimes). In effect, this means that the scale is linear in terms of proportional changes (percentages). In this way, all the indices were effectively reduced to dimensionless numbers on an ordinal (rank) scale in the ESPON/Hazard GIS database.

3 RESULTS

The maps presented in Figures 1–4 are based on regional climate model data with a spatial resolution of 50x50 km. Map 1 provides an example of a ESPON/Hazards NUTS 3 region map derived from the ESPON GIS system.

As expected, the four temperature indices show a very clear and general north-south gradient modulated by topographical variations. This pattern follows the general climate zonation of Europe. Focussing on the spatial pattern of projected climate change, the *Cold day* index, (Figure 1, left) shows the strongest change in the continental eastern regions where the dampening effect of the ocean is less dominant. The *Coldwave* (Figure 1, right) shows a stronger change signal, where a large part of western Europe may see a change towards conditions presently occurring mainly in the Iberian Peninsula. For both indices, the overall picture is a shift from southwest to northeast in climate zonation. This is a combined effect of the dampening effect of the maritime situation of the western parts and the warming trend that causes a reduction in snow cover, which leads to more solar radiation being absorbed by the snow-free ground.

In both the *Hot day* and *Heatwave* indices (Figure 2) there is a clear shift in the south-north direction. Large parts of Europe may see a shift towards temperature extreme conditions that now occur mainly in Mediterranean North Africa and the northwestern Iberian Peninsula. In a similar way, the high extreme temperature climate of France, Germany and Poland may move northwards towards the British Isles, southern Scandinavia, and southern Finland. The least changes are projected for northern Scandinavia and northern Finland. The general warming trend will directly increase the warm extremes, but this is further enhanced by the direct effect of a decrease in soil moisture during the summer. Thus, there is an interaction between an extended summer dry season (see below) and warm extremes.

Also, the two precipitation indices, the *Heavy Precipitation* index (Figure 3, left) and the *Wetspell* index (Figure 3, right), show a close agreement in the overall geographical distribution. Both indices clearly show the close relationship between precipitation and orography. High amounts of precipitation generally occur on the upwind slopes when moist air from the sea is lifted above a mountain range. For the *Heavy precipitation* index, which is intended to pick up high-intensity downpours, the amounts given in the maps are averages for the whole gridbox of ~2500 km^2, which typically is an area much larger than the size of a locally intensive rainstorm. Consequently, the local rainfall amount within a gridbox may be much higher while large parts of the same gridbox receives no or only little precipitation.

The overall picture is that, according to the model ensemble scenario all of Europe, except for the southern part of the Iberian Peninsula, will see an intensification of heavy precipitation and 7-day wet spells by some 10–30%. The southern part of the Iberian Peninsula will however experience less intensive precipitation events. These results are consistent with the analyses from a single RCM (Semmler and Jacob 2004).

Finally, the *Dry spell* index (Figure 4) indicates a general increase in the persistence of long dry spells (meteorological droughts), with the exception of

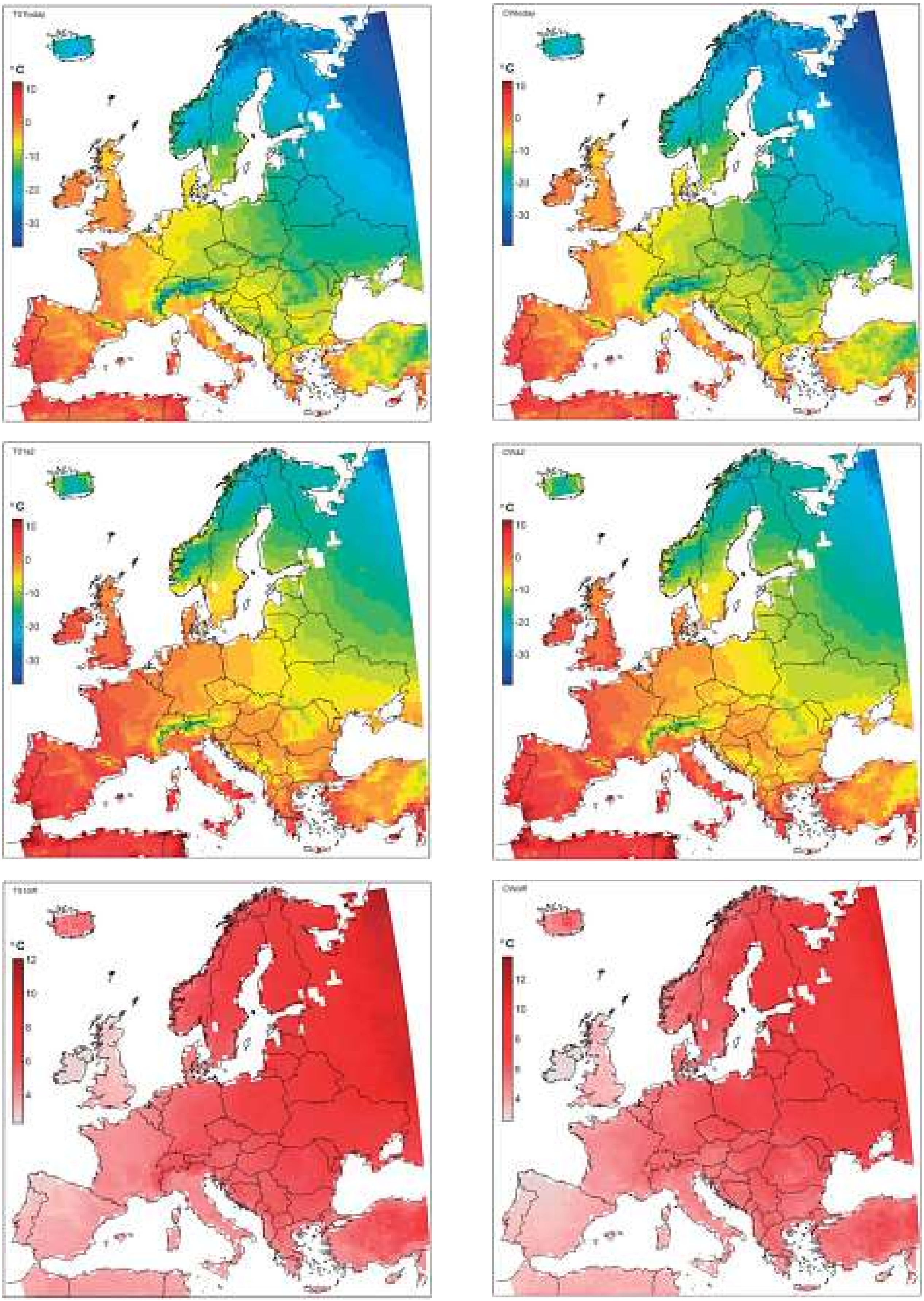


Fig. 1. Winter cold conditions derived from an ensemble of regional climate models. Left column is the 1st percentile of daily mean temperatures, and the right column is the 7-day coldwave index (cf. Table 2). Top row shows the present day (1961–1990) conditions, middle row shows the future (2070–2099) conditions for the SRES A2 greenhouse gas concentration scenario. The bottom row shows the climate change signal, that is, the difference future minus present day conditions.

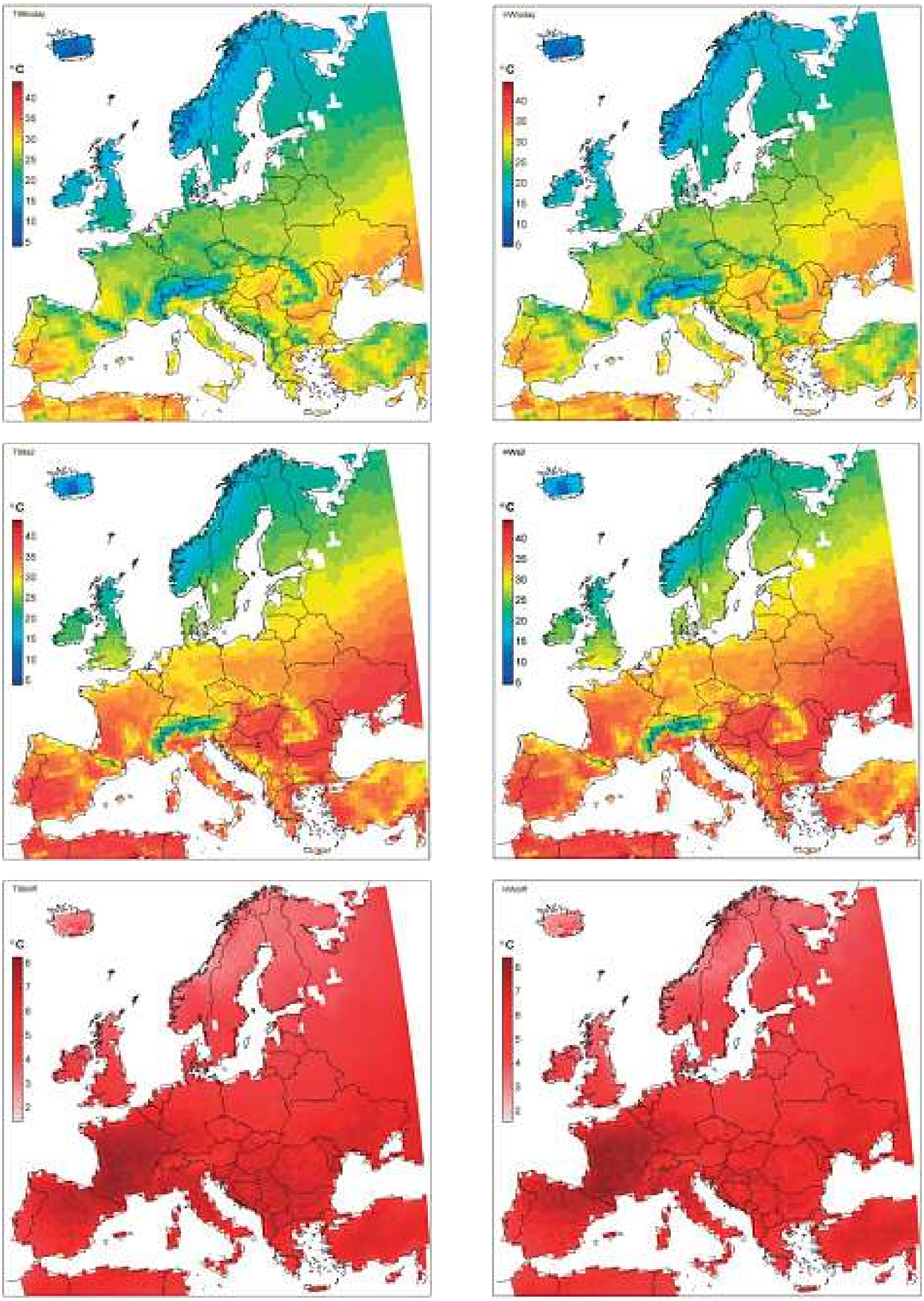


Fig. 2. Summer warm conditions as estimated from an ensemble of regional climate models. Left column is the 99th percentile of daily mean temperatures, and the right column is the 7-day heatwave index (cf. Table 2). Top row shows the present day (1961-1990) conditions, middle row shows the future (2070–2099) conditions for the SRES A2 greenhouse gas concentration scenario. The bottom row shows the climate change signal, that is, the future minus present day conditions.

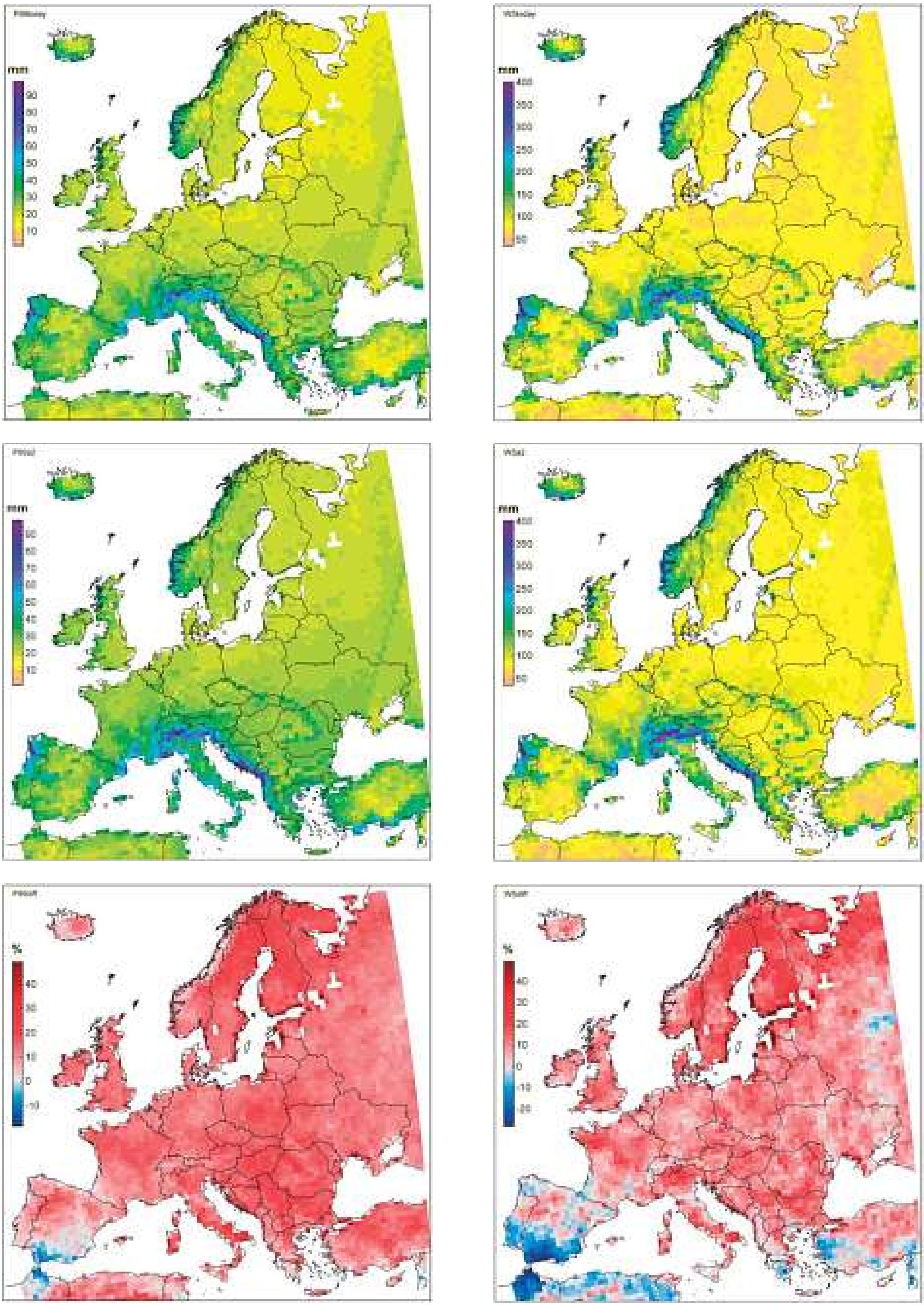


Fig. 3. Precipitation conditions as estimated from an ensemble of regional climate models. Left column is the 99th percentile of daily total rainfall for wet days, and the right column is the 7-day wetspell index (cf. Table 2). Top row shows the present day (1961–1990) conditions, middle row shows the future (2070–2099) conditions for the SRES A2 greenhouse gas concentration scenario. The bottom row shows the climate change signal, that is, the percentage change compared to present day conditions.

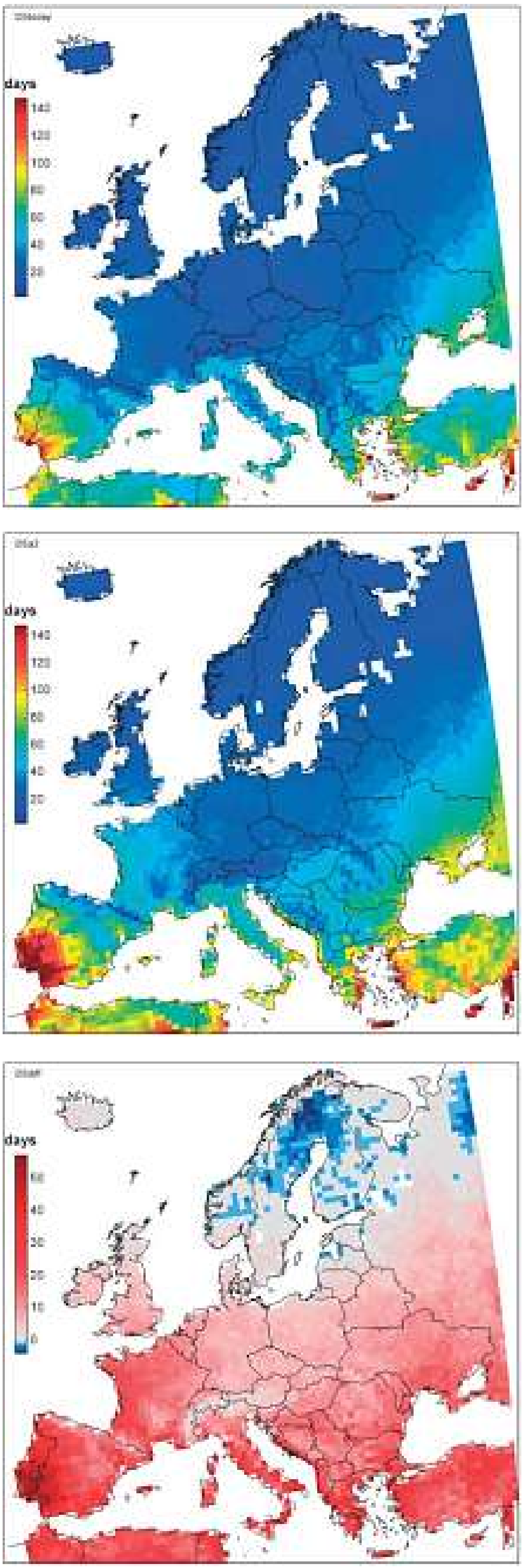


Fig. 4. Dry spell index (cf. Table 2 Dry spell) derived from an ensemble of regional climate models. The index is defined as the longest period of dry days. Top row shows the present day (1961–1990) conditions, middle row shows the future (2070–2099) conditions for the SRES A2 greenhouse gas concentration scenario. The bottom row shows the climate change signal, that is, the future minus present day conditions.

northern Scandinavia. In southern Europe, this dry spell is of course centred during the dry summer season, but in northern Scandinavia the driest season often occurs during spring. The Mediterranean coastal regions, in particular the Iberian Peninsula, today has a long summer dry period that is projected to become even longer in the future. Large parts of southern Europe may see the summer drought extended by 1–2 months. In a single-RCM study, Christensen and Christensen (2004) found that the overall decrease in summertime precipitation largely follows our results and they also found that heavy precipitation events increase in southern Europe. In northern Europe, the extension is less pronounced, about 10–30 days. In northern Scandinavia, the dry episodes may be shortened by a few days, but this is unlikely to have any significant impact.

The drought hazard map (Map 1) is an example of a typology of European regions based on the *Dry spell* index and a classification on drought potential based on observed precipitation deficits 1904–1995 (amount 2–8). When comparing Figure 4 and Map 1, the effect of introducing the drought potential is evident, especially for Italy and Belgium. It should be noted that the drought potential is based on historically reported drought events with variable accuracy (Alavarez and Estrela 2001). The aggregation onto NUTS 3 regions also introduces a variable spatial smoothing depending on the region size.

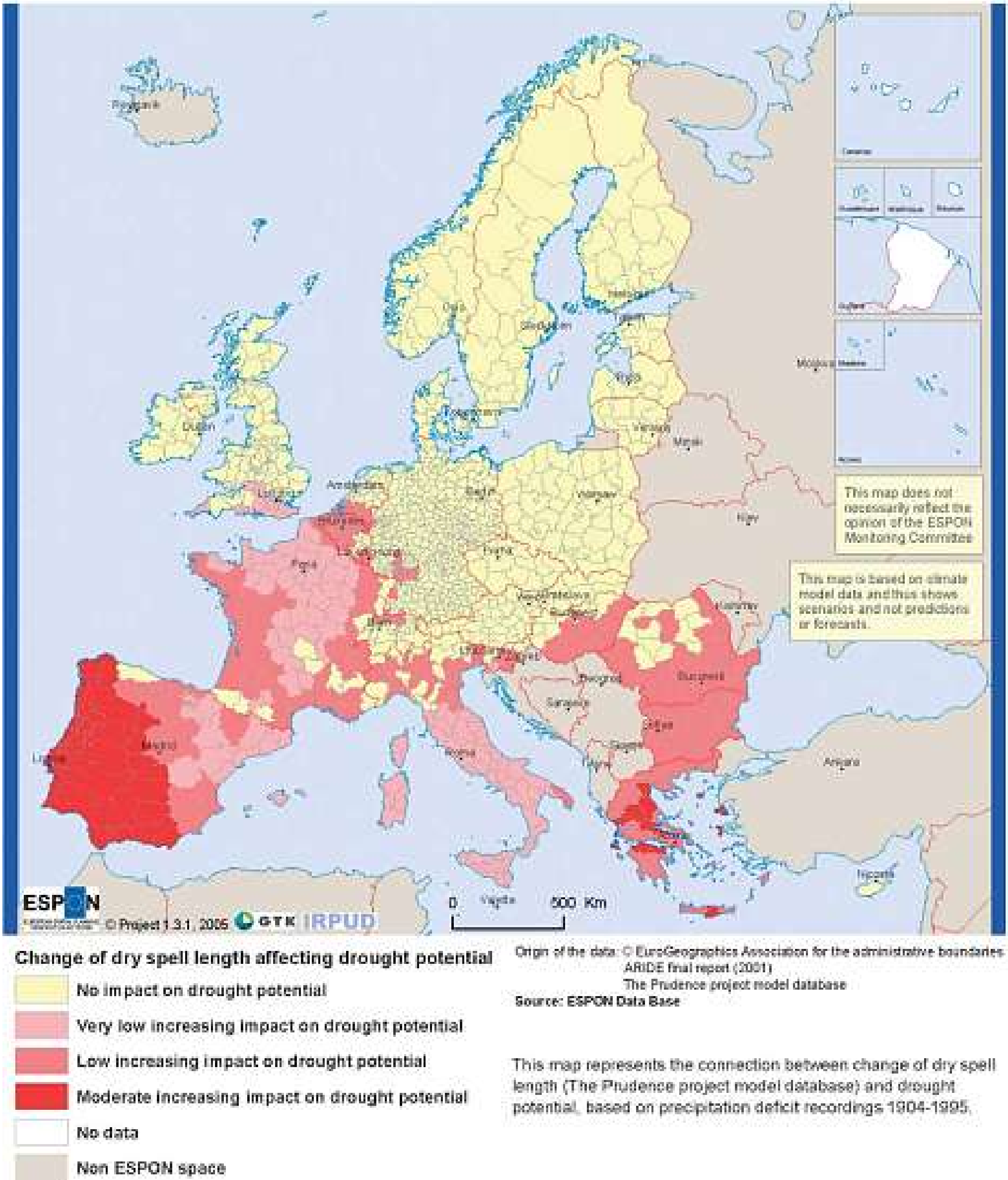
4 DISCUSSION

The indices of climate extremes presented here are representative examples from a large set of indices currently under investigations. They were selected to show changes to wintertime cold extremes, summertime hot extremes, as well as changes to extreme precipitation and dry spell events. Climate extremes are, by definition, rare and often spatially limited. Their interactions with other localised factors, results in every severe impact incident having its own unique characteristic. These indices of climate extremes provide general information on the climate component of natural hazards. More specific indices will have to focus on specific impact sectors, and will likely be regionally focused. The following hypothetical examples may serve to illustrate the multi-dimensional nature of the problem and the need to address the problem of climate extremes in a targeted way.

Cold extremes, like the one in January 1987, are projected to become less frequent, thus substantially reducing one particular type of climate hazard. However, the generally warmer climate will lead to reduced snow cover and ground frost, and thus influencing other natural hazards (cf. Table 1). In addition, the ecological impact of changing snow cover and ground frost distribution has yet to be established with regards to species distribution, and the survival of pests and pathogens.

The January 2005 windstorm over southern Sweden (“Gudrun”) caused catastrophic forest damage that resulted in extensive disruption to the electrical power grid and telecommunication networks. Interestingly, within less than a week two other storms of equal intensity occurred over the North Sea. One storm followed a more northerly track along the Norwegian coast and the other, which was of the same intensity as “Gudrun”, quickly weakened when it reached the Swedish coast. While much of the most susceptible forest had already fallen, the root system of many trees was damaged and the already very dangerous rescue and maintenance work would have become even more difficult. If, on the other hand the windstorms had followed a more southerly track, Germany for example, may have experienced the same kind of problems as Sweden. However, the rebuilding of the electricity power network may then have been much more difficult because Swedish operators had already acquired all available stocks of key supplies. This hypothetical example shows that the sequence of storm events, their relative timing and the regions affected can have widely different impacts on society.

Another hypothetical example is if the 2003 summer heat wave over southern and western Europe had been repeated one or two years later. For several reasons the impact would probably be less catastrophic in terms of the death toll. One reason is that authorities then would have had the experience from the 2003 situation to build on and preventive measures would have being taken, which would make society less vulnerable and better prepared. Another important factor is that the most fragile and sensitive persons did not survive the 2003 heat wave. It is worth noting that in other regions, like North Af-



Map 1. A drought hazard map derived from the ESPON Hazards project's GIS system. The information is based on observed precipitation and the change of the Dry spell index (Figure 4, bottom) that were ranked into six classes and aggregated onto the NUTS 3 regions. For this presentation, the six classes were further reduced to four classes. Source: Schmidt-Thomé 2005.

rica and the Middle East, similar heat spells commonly occur without any severe impact because the society and population is adapted to the climate conditions. This points towards the two main ways towards adaptation: through deliberate and planned societal measures to decrease vulnerability, and the more basic natural course of events that a less well prepared society would be subjected to.

This discussion leads us towards a hypothetical issue of some practical principle importance from a policy-making point of view. If it were possible to conclude that recent catastrophic natural hazard events were within the natural climate variability, the implication would be that society is not fully prepared to cope with such events that are not under the additional strain introduced by a changing climate. However, if the observed climate change (the increase in global/hemispheric temperature) had already begun to influence the frequency and intensity of climate extremes that underlie natural hazard events, then society would be successively less prepared for natural hazards (and indirectly technological hazards) triggered by climate extremes.

In the first case, those responsible for taking preventive measures against climate extremes may act under the false impression that they are adapting to a climate change, while in fact they are only responding to insufficient protection against present day 'normal climate variability'. The difference between responding to present-day climate under the perception of adapting to a future climate change is substantial from a policy- and decision-making point of view.

If policy-makers are asking tax-payers for funding, and acceptance of costly adaptations to a perceived climate change when the planned measures are in fact only handling deficiencies in adaptation to present day climate, it will probably be much more difficult to again ask for support for adapting to a real climate change.

In either case, statistical summaries of annual losses due to extreme weather published by insurance companies unanimously confirm a trend towards increasing insured losses due to the impact of climate extremes. The important issue lies in the awareness of climate vulnerability and perception of climate change by the decision-makers.

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SPATIAL PLANNING RESPONSE TOWARDS NATURAL AND TECHNOLOGICAL HAZARDS

by
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Greiving, S. & Fleischhauer, M. 2006. Spatial planning response towards natural and technological hazards. Natural and technological hazards and risks affecting the spatial development of European regions. *Geological Survey of Finland, Special Paper 42,* 109–123, 3 figures, 2 tables.

This volume focuses on the response of spatial planning to hazards. This implies a concentration on risk *management* whereas risk *assessment* is discussed in most of the previous articles in this volume Spatial planning response has to be understood as acting on a concrete spatial level – the region and the local communities. Although a lot of risk related activities take place on these levels, only a few of them are really part of spatial planning, understood as the formal planning system of a country consisting of a set of plans and programmes and incorporated measures. This set of instruments and measures will be described in this volume However, the planning perspective towards hazards needs to be discussed, followed by a process-oriented view on planning. In addition, the responsibilities of the different actors involved in risk assessment and management have to be clarified.

Keywords: natural hazards, spatial planning, regional planning, urban planning, risk assessment, preventive measures

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1 THE PLANNING PERSPECTIVE TOWARDS HAZARDS

Space can be defined as an area where human beings and their artefacts are threatened by spatially relevant hazards. The reaction of tolerating or altering risk can be understood as an integrated part of the given socio-economic structures with spatial planning as a certain part of a reaction.

Spatial planning makes decisions for society regarding if and how certain spaces will be used. Therefore, spatial planning more or less influences vulnerability in cases of existing spatially relevant natural and technological hazards. The spatial character of a hazard can either be defined by spatial effects that might occur if a hazard turns into a disaster or by the possibility of an appropriate spatial planning response. This also opens up questions about the relevance of different levels of spatial planning as well as the relationship to sectoral planning. Furthermore, the nature of spatial planning strongly requires a multi-risk approach that considers all relevant hazards threatening a certain area as well as the vulnerability of this area instead of a science area (sectoral, like in many natural sciences; Fleischhauer 2005 Spatial relevance of natural and technological hazards, *this volume*.

Each hazard has a spatial dimension (it takes place somewhere). However, spatially relevant does not yet mean spatial planning relevance, but nevertheless it might be of interest for a sectoral planning division or an emergency response unit.

One of the most serious problems in this context is represented by the so called external effects: a spatial and temporal inconsistence between chances and risks which are related with every decision making about a future land-use or a concrete investment at a certain location. A classic example for this planning problem is represented by the (intra-generational) conflict between actors which are located upstream and downstream: A municipality located upstream might profit from the chances of a suitable location for an industrial area located in the flood plains of a river and could protect this area by means of a dike. The direct consequence of this action would be among others an increased flood risk for downstream located areas, because of the reduced flood plain capacities in combination with flood waves which would occur faster and with a higher peak.

In terms of sustainable development, this conflict can be described as an *intra*-generational conflict. Aside from this, *inter*-generational aspects have to be taken into consideration. Inter-generational justice can be understood as a second prerequisite for reaching a balance of chances and risks. Rawls, who founded a civilisation theory called "*Theory of Justice",* based the necessity of a consensus about normative regulations on a consensus with the righteous interests of future generations instead of just a consensus of people who are actually alive now. He argues that the so-called "*Veil of Ignorance"* or the view of short-term chances hinders an appropriate estimation of long-term negative affects that might threaten mainly future generations (Rawls 1971, 328f). In this context, the greater the persistence of possible harmful effects of an event or decision, the greater the importance and problems related to a decision that accepts consequences from hazardous events (Berg et al. 1995, 30ff).

Godschalk et al. referred to an illustrative example from San Francisco. The Chief Building Inspector had justified a governmental responsibility for building safety standards after the Loma-Pieta-earthquake as follows: "I represent, in absentia, the unknown future user" (Godschalk et al. 1999, 494). This example indicates that planning related decisions based on a consensus of all stakeholders could fail in relation to the temporal and, as mentioned above, spatial dimensions. The same decision is possibly based on free market transactions. Even if all participants of a transaction of land designated for construction would come to an agreement, they might fail in relation to an unacceptable use of common pool goods.

Following this argument, the link from the discussion about risks to the principle of sustainable development becomes clear. Moreover, taking into account the interests of future generations, the necessity for regulative spatial planning is clearly visible. Such decisions are based on normative findings, made by supranational (like the EU) or national policies as a framework for regional and local weighting-up processes within spatial planning.

This approach leads to a process-oriented understanding of risk management as a task for spatial planning. Spatial planning has to anticipate the consequences (or chances and risks) of actions from the beginning of a planning process, as part of the planning goal findings. In addition, a continuous evaluation and review of fixed planning goals, implemented measures and their effects on the environment should be taken into account.

The core elements of sustainable development, carried out in the Rio Declaration in 1992 should be kept in mind. The development of societies cannot be sustainable in view of increasing risks from natural and technological hazards (Lass/Reusswig/Kühn 1998, p.1). The US National Science and Technology Council has pointed out that "Sustainable development must be resilient with respect to the natural variability of the earth and the solar system. The natural variability includes such forces as floods and hurricanes and shows that much economic development is unacceptably brittle and fragile"(FEMA 1997, p.2). Godschalk et al. argued "that a resilient community is one that lives in harmony with nature's varying cycles and processes". This includes events like earthquakes, storms, and floods as natural events, which cause harm only for a non-sustainable society (Godschalk et al. 1999, 526).

As a result, a fourth criterion should be added to sustainability's economic, social and ecologic aspect (Greiving 2002, 203). Sustainability can be understood as a mission for the development of mechanisms for adaptation of societies to future consequences of present processes.

The development of a detailed set of instruments and measures that act as a kind of restrictive constraint for planning practice must fail because of the nature of planning. Even from a theoretical point of view and given the unpredictability of the development of societies and natural processes, it is impossible to create measures that could be valid for each individual case and context of planning. Furthermore, the large number of relevant hazards, which might interact with the result of cumulative effects, has to be taken into account. Finally, because of the variety of planning systems and the multitude of natural and socio-economic settings and the pre-existing differences in the national planning systems, a formulation of coherent instruments or concrete mitigation measures is nearly impossible.

Thus, the formulation of guidelines for harmonizing a successful planning process and set of methodologies seems to be more promising than the formulation of general measures that should fit all hazards. In this context, it is important to stress that municipalities do not necessarily know about information sources, existing actors and contacts, the cost and effectiveness of different measures. In such situations, the existence of any kind of support for the introduction of a risk management process on a local level by means of a guideline or a handbook for risk management can be seen as a strength.

In this context, harmonised risk assessment methodologies can be understood as crucial for valid and comparable results of risk assessments within a threatened area (see Chapter 8 – Integrated risk assessment of multi-hazards).

2 RATIONALITY BY MEANS OF PROCEDURAL REQUIREMENTS

The theoretical steps of a planning process will be described and complemented by a description how steps of risk assessment and management can be integrated into the spatial planning process. Looking at different visualisations of planning processes, a large variety of flowcharts, like the "classic" flowchart of a planning process by Harris (1967, 325) can be identified. However, a closer look shows some basic similarities that are typical for every planning process (see Figure 1).

Normally, a planning process will begin when certain conditions in the real world are regarded as unsatisfactory or demanding urgent action. The first phase of a planning process is therefore called problem analysis. A prerequisite for the identification of problems is the observation of the environment by planners or other persons and the description and assessment of the existing information. To avoid an unnecessarily high effort of data collection, planning targets should be fixed and goals developed describing the desired future condition. Such goals are not determined in general but are to be seen as rather flexible and always underlie certain changes. When collecting the respective data, it is important that only those data be surveyed that are necessary for describing the relevant conditions. Then an analysis of the existing conditions can be made on the basis of the deliberately collected data. The aim of such an analysis is to identify the dependencies, interactions and interrelations between the observed circumstances and influencing variables.

In the second phase, the necessary measures can be determined after planning alternatives have been assessed. Experience has shown that the development of alternatives under thorough consideration of all aspects that come into question generally lead to good results. In this context, it is indispensable to also estimate the possible impacts of alternatives. To assess the alternative measures, a detailed discussion of the presented alternatives should be made. A cru-

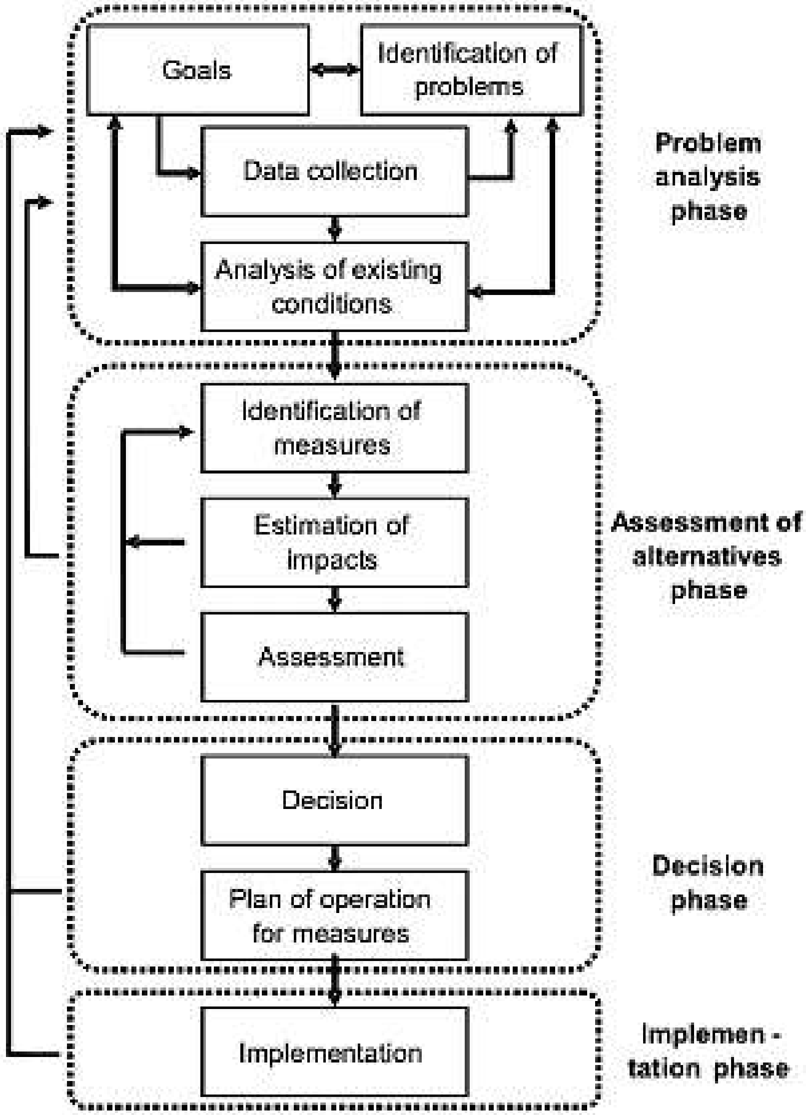

Fig. 1. Planning process. Source: Schmidt-Thomé 2005.

cial point is to examine if and to what extent the different measures serve to fulfil the desired goals. The more complex the alternatives are, the more likely formalised assessment methods like cost-benefit analysis or value-benefit analysis have to be taken into consideration.

After the discussion of all alternatives has been completed, the third phase of the planning process can begin. Now a decision can be made about which suggestion is considered to be the best. Simultaneously, the necessary measures for the realisation of the selected alternative can be determined and prepared.

The implementation of the selected alternative results in a change of the initial conditions. In general, it is necessary to examine if the projected impacts and improvements have occurred or if unexpected (and often undesired) side effects have emerged. In the meantime, the general conditions might have changed and as a result of previous plans, new problems could arise that require the planning process to start from the beginning. Of course, in reality a planning process seldom works in such an ideal way but rather has to be adjusted to certain circumstances.

Very well designed measures often have absolutely no effect because of the existence of typical planning related problems (like fit, interplay and scale). The problem of interplay is an especially crucial factor for mitigating spatial risks. Most institutions interact with other similar institutions both horizontally and vertically. Horizontal interactions occur at the same level of social organisation. Vertical interplay is a result of cross-scale interactions or links involving institutions located at different levels of social organisation. Interplay between or among institutions may take the form of functional interdependencies or arise as a consequence of politics of institutional design and management (Young 2002, 19 ff.). The problem of interplay is a consequence of the existence of a multitude of actors. Normally, national planning systems hold a second, sectoral dimension with its own organisational units, instruments and authorities. The differences in purpose between the various authorities does not permit any internal harmonisation through a common superior authority. The relationship between comprehensive spatial planning and sectoral planning divisions is a crucial factor for mitigating spatial risks. Nevertheless, in contrast to spatial planning, the EC has strong legal competencies and hence a great number of powerful directives in the field of sectoral planning, especially environmental planning (see SEVESO II Directive; Flora Fauna Habitat Directive, Water Framework Directive).

The problem of interplay shows that the process area plays an important role in a successful planning response to risks. In the following, risk assessment and management will be understood as the systematic application of management policies, procedures and practices to the task of identifying, analysing, assessing, treating and monitoring risk. The following explanations go hand in hand with the flowchart of a risk assessment and management process (see Figure 2):

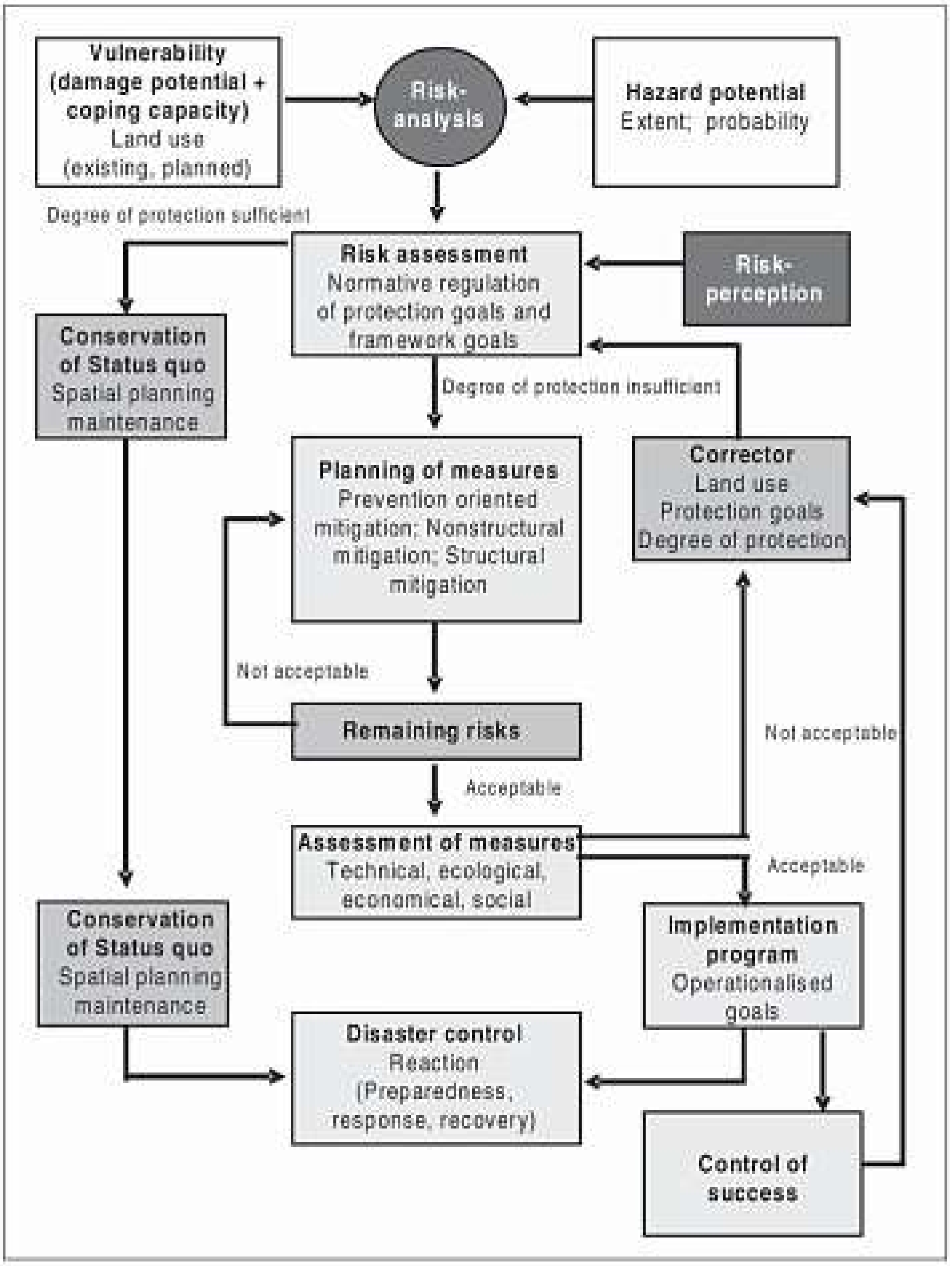

Fig. 2. Risk assessment and management process (Greiving 2002, p. 248).

Risk assessment

The starting point of the risk assessment is the identification of hazards. This task is mainly a determination based on scientific and technical findings. Identification, as well as analysis of hazards and risks are mainly tasks for the sectoral planning divisions due to their specific competencies. For that reason, an early and full coordination between the spatial planning authority (who is in charge of the preparation of zoning instruments for example) and the relevant other authorities involved, would be an essential prerequisite for an effective planning process.

This scientific, deterministic approach also characterises the next step, the risk analysis as a mathematical calculation that includes the analysis of a hazard and its consequences. The risk analysis can be understood as a description of certain hazards and their element's frequency of occurrence (hazard component) and magnitude of consequences (risk component), respectively. Similar to hazard identification, the spatial planning authority requires the support of the sectoral planning divisions as well. In the best case, the necessary information could be gained from existing hazard and risk maps with, of course, an appropriate spatial scale. However, a harmonised risk mapping methodology can be as crucial for the quality of the results and the comparability between the risk assessments made by different planning authorities within one area that is threatened by a certain hazard.

With regard to risk perception, it should be noted that sometimes those who did not study the relevant statistics draw conclusions of certain risks from a significantly "incorrect" (from a statistical perspective) judgement of the probabilities of potentially hazardous events (so called heuristics). However, risk perceptions are a fact of life that shape, for instance, policy, legislation and mitigation efforts. Therefore risk perceptions can be seen as incorporated in norms, practices and probability calculations. There are many factors known to affect an individual's perception of risk, namely familiarity with a risk, control over the risk or its consequences, proximity in space, proximity in time, scale of the risk or general fear of the unknown (the so called "dread factor"). Apart from these factors, individual risk perception is also shaped by how the community or a certain socio-cultural milieu generally deals with a special type of risk or risky situations.

An important and interesting aspect of risk perception is the variation in different cultural (regional, national) contexts, a perspective studied within the cultural risk paradigm. Risk perception enters the risk management equation through differing estimations on, for example, how probable an event may be, and how much money is to be spent on preparedness. Furthermore, individual risk perceptions are to be distinguished from the way "institutions think" (Douglas & Wildavsky 1982).

Risk evaluation consists of the outcome of risk analysis and risk perception (the overall view of risk held by a person or group that includes both feeling and judgement). Risk analysis on its own is partly subjective because the precise knowledge required to be truly objective is rarely available (for example, full information about frequency and magnitude). Thus, it could be right that decisions are made partly in response to pressures generated by perceptions of risk. Due to this fact, extensive public participation ‑would be a suitable indicator for fulfilling this requirement.

In the end of risk assessment, an objective weighting of all significant effects on the environment will be carried out. This assessment is an essential task for the spatial planning authority and has to be integrated into the weighting process.

Risk management

Risk management can be understood as a process of implementing decisions that aims at tolerating or altering risks. Risk management consists of four stages that are often illustrated in the so-called risk or disaster management cycle:

1. Mitigation: The reduction or elimination of long-term risk to human life and property from any kind of hazard taking place well before the disaster occurs. Typically carried out by a co-ordinated mitigation strategy or plan. While mitigation is characterised by long-term actions, the last three points (preparedness, response and recovery) focus on short-term actions in case of a disaster and therefore can be seen under the term of reaction.
2. Preparedness: This means short-term activities, such as evacuation and temporary property protection, undertaken as soon as a disaster warning has been received.
3. Response: This term indicates short-term emergency aid and assistance, such as search-and-rescue operations, during or following the disaster.
4. Recovery: This constitutes the last step of post disaster actions, such as the rebuilding or retrofitting of damaged structures.

The effectiveness of disaster response or risk management, respectively, depends on the coping capacity. The notion of capacity refers to coping capabilities and clearly points towards "institutional preparedness". According to the UNISDR definition, capacity refers to "the manner in which people and organisations use existing resources to achieve various beneficial ends during unusual, abnormal, and adverse conditions of a disaster event or process. The strengthening of coping capacities usually builds resilience to withstand the effects of natural and other hazards" (UNISDR 2005). To a large extent, coping capacity includes "institutional preparedness", which is considered to be one of the main aspects of how spatial planning deals with hazards and risks. The strengthening of coping capacities usually builds resilience to withstand the effects of natural and other hazards.

Decision making as a core element of risk management is a normative, politically influenced strategy of tolerating or altering risks. The authority in charge (normally democratically legitimised) has to decide about the main planning goals that are related to dealing with hazards. For example, what are the protection goals for the different protection objects threatened by specific hazards or what are the foreseeable environmental effects from a planned object in the case of a hazardous event occurring? From a cost-benefit point of view, it is indispensable to set the protection goals in relation to the protection objects. While it is useful to protect a highly vulnerable industrial facility or a settlement area against rarely occurring extreme events, protection of single estates or farmland areas is more or less inefficient. However, this kind of decision requires an adequate information basis that has to be taken into account in the decision making process.

Appropriate measures have to be taken as an integrated part of decision-making for the respective plan or programme with regards to the defined protection goals. These measures or alternatives, respectively, can be differentiated into prevention-oriented mitigation, non-structural mitigation and structural mitigation. Moreover, measures regarding disaster preparedness, response and recovery should be an integrated part of a risk management process. Each measure has to be evaluated based on its technical functionality, economic costs and efficiency as well as social and ecological effects.

The implementation of measures is an integrated part of the implementation of the plan or program by the planning authority itself and/or other planning authorities in charge of sectoral tasks. For that reason, sectoral planning divisions, as well as emergency control units, should be part of this implementation process. Otherwise, companies or private stakeholders who are the addressees of a certain plan or program could be responsible for the improvement of their own buildings or facilities.

An important part of a risk management process consists of monitoring the effects of implemented measures. Monitoring represents how the outcome of the risk assessment has been carried out, confirmed or not confirmed in comparison to the original data base. For such monitoring, an indicator-based concept would be suitable for distinguishing between the hazards and protection objects. Such indicators should answer the question of whether the chosen measures are able to fulfil the determined protection goals or not. For the case of given differences between goals and observed effects, a reformulation of goals or the development of new measures should be taken into consideration.

Risk assessment and management as elements within the decision process about spatial plans can be structured along three main lines of argument:

1. *Scientific basis:* Is there appropriate data, are the necessary data and assessment methods available (hazard maps, risk maps) for developing a scientifically correct foundation for the decision making process?
2. *Political decisions:* To what extent is the scientific basis considered when political decisions have been made? What are the reasons for neglecting information about hazards and risks? How and to what degree had the results of risk assessment been taken into account when deciding on specific plans or programs?
3. *Implementation process:* How sure will a measure be implemented (e. g. reconstruction of a dike), when a decision once has been made? What are the possible hindrances?

Figure 3 shows how these three lines of argument are incorporated into the planning processes.

Risk assessment and management should be incorporated within the spatial planning process to achieve greater sustainability and at least resiliency of society's development by means of procedural and methodological requirements.

To reach this purpose, a formal framework that follows this approach as well as a harmonised risk assessment methodology will be required. For that purpose, the directive 2001/42/EC ("Strategic Environmental Assessment"; European Union 2001) should be discussed. An environmental report shall be prepared in which the likely significant effects on the

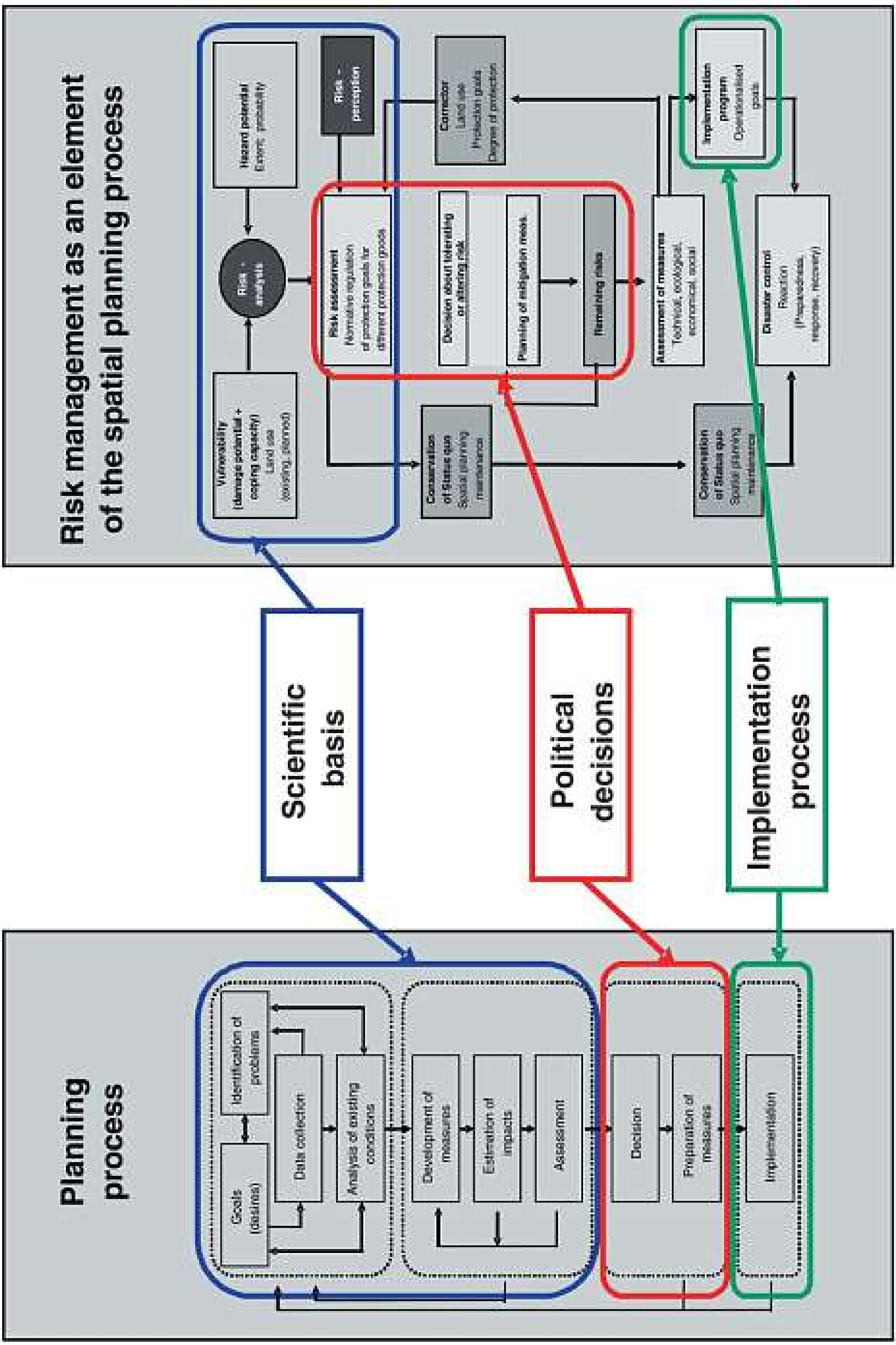

Fig. 3. Risk assessment and management as planning process. Source: own figure.

environment of implementing a plan or programme are identified, described and evaluated. Damage potential is covered by the SEA issues "human health", "material assets", "cultural heritage" (Annex I). Annex II points out the characteristics of the effects and the area likely to be affected. Several risk-related aspects have to be regarded specifically (like probability, magnitude, vulnerability, spatial extent of the effects). An increasing damage potential or influence on the hazard potential as a consequence of the implementation of a plan can be understood as a significant effect on the environment. SEA is well established by legislation and can be described as an existing common procedural framework for managing risks threatening the environment.

However, although spatial planning has to incorporate hazard and risk related information in decision-making, spatial planning to a certain extent, is the only responsible actor for risk assessment and management itself.

3 RESPONSIBILITIES OF SPATIAL PLANNING IN RISK ASSESSMENT AND MANAGEMENT

Hazard assessment is naturally a task for sectoral planning authorities like water boards, and geological surveys. Spatial planning plays a minor role in this context. Nevertheless, spatial planning can be understood as one important end-user of hazard related information, provided by sectoral planning. To meet the requirements of spatial planning, minimum standards for hazard mapping are indispensable. However, attention is paid to vulnerability only in a few cases. From a planning perspective, all that information is needed that is not available or at least ascertainable by spatial planning itself. This means that in the first instance, hazard related information has to be provided by sectoral planning. This information includes intensity and magnitude of potentially harmful events, caused by certain hazards. In contrast, vulnerability-related information are, in most cases, known in spatial planning because facts like the distribution of population, the location of settlement areas, or technical infrastructure is basic information required for any kind of planning activity (Greiving, Fleischhauer and Wanczura 2005).

Planning is responsible mainly for future land-use. Thus, vulnerability-related information is less important compared to a given hazard potential. The usual method in planning practice can be seen in certain settlement restrictions for threatened areas. However, such decisions have to be understood as a kind of non-structural mitigation measures. These measures have different consequences for different protection goods (what do you mean by goods?), and while any kind of settlement or building activities might be prohibited in cases of inhabited buildings, other facilities might be permissible. Special attention is paid to especially vulnerable infrastructure (schools, and hospitals) and dangerous infrastructure (e.g. chemical plants). Vulnerability related information in spatial planning is only relevant for risk **management** whereas no risk **assessment** is needed. This is seen particularly in the results of the analysed planning practice (Greiving, Fleischhauer and Wanczura 2005).

Nevertheless, integration of vulnerability related information is indispensable as a part of integrated concepts that cover the whole disaster circle. Best practice in risk management is based on integrative concepts that cover structural and non-structural mitigation measures, preparedness and response elements. As a result, their perspective has to be much broader than only land-use oriented, which makes use of spatial planning. In this context, spatial planning can be understood only as one important supporting actor. Risk management measures of municipalities make use of land-use planning (as well as other instruments); however, land-use planning does not generally promote risk management in an active manner.

Thus, this volume focuses on the potential role of spatial planning as one important actor in risk management, while at the same time several other actors are responsible for the assessment and for certain risk management measures. In general, the responsibility for integrative risk management concepts lies, in most cases, on authorities that are in charge of disaster management (e.g. the FEMA in the U.S.) or at least those authorities that have a wide range of competencies (like the municipalities on the local level). The practical competency limitations of spatial planning will be illustrated using examples from existing mitigation handbooks.

The US Federal Emergency Management Agency has published a series of guides to assist states, communities and tribes in enhancing their hazard mitigation planning capabilities (FEMA 2001; FEMA 2002a; FEMA 2002b; FEMA 2003a; FEMA 2003b). These guides shall provide all necessary information that state and local governments need to initiate and maintain a planning process aimed at safer communities (FEMA 2002a, p. i). A look at the handbooks shows that land-use planning indeed only plays a minor role among other actors as well as concerning the measures that can be taken:

– *Actors:* The list of possible actors to be included in a mitigation planning team suggested by FEMA shows that the Planning and Zoning Office is mentioned as one of many other actors including the Administrator/Manager's Office, Budget/Finance Office, Building Code Enforcement Office, City/County Attorney's Office, Economic Development Office, Emergency Preparedness Office, Fire and Rescue Department, Hospital Management, Local Emergency Planning Committee, Police/Sheriff's Department, Public Works Department, Sanitation Department, School Board, Transportation Department, and Tribal Leaders on the local level (FEMA 2002a, p. 2–17).
– *Measures:* Similarly, planning and zoning is only one aspect within the mitigation action category of prevention. Other examples of prevention actions include building codes, capital improvement programs, open space preservation, and storm water management regulations. Apart from prevention, the whole mitigation action consists of other categories like property protection, public education and awareness, natural resource protection, emergency services and structural projects. These categories include measures in manifold areas. (FEMA 2003a, p. 2–1).

The Portland, Oregon Metropolitan Area published a "Regional Hazard Mitigation Policy and Planning Guide", which identifies actions to prevent loss in all communities and encourage development of a disaster resistant region (POMA 1999, p. 4). The guide identifies six classes of mitigation actions: prevention, property protection, emergency services, protecting civil facilities, and structural projects with specific goals and objectives assigned to these classes. Land-use planning only plays a role within the class of prevention actions where only two of six goals and two of four objectives explicitly mention land-use planning (POMA 1999, p. 19f.).

Examples from both handbooks show that spatial planning in practice only plays a supportive role in the management of natural and technological risks.

4 SUITABLE INSTRUMENTS AND MEASURES OF SPATIAL PLANNING TO BE USED FOR RISK MANAGEMENT PURPOSES

Risk management is defined as adjustment policies that intensify efforts to lower the potential for loss from future extreme events. This definition shows that risk management is characterised by decisions of stakeholders. Decision-making is a normative, politically influenced strategy about tolerating or altering risks. The authority in charge (democratically legitimised) has to decide the main planning goals to deal with hazards The action decided upon is the result of a weighting process. The following questions are of concern in this context:

– What is the level of risk society (or any stakeholder) is willing to accept?
– What are the protection goals for the different protection objects that are threatened by specific hazards? or What are the foreseeable environmental effects from a planned object in case of an occurred hazard?

When talking about risk management, we always have to decide between the regional and local level. Therefore, it must be clearly indicated which objectives, instruments etc. can be applied on the regional or local level.

Seen from the broader risk management point of view, risk management consists of mitigation, preparedness, response and recovery. At the same time, planning responses at several planning levels can be attributed to the respective risk management strategies, although spatial planning responses are concentrated mainly on non-structural mitigation measures.

Table 1 differentiates between regional planning, land-use planning and sectoral planning. Supporting instruments are also mentioned. The role of regional planning, as well as land-use planning, will be discussed in more detail.

4.1 Regional Planning

4.1.1 Prevention oriented mitigation

In this context, spatial planning on the whole plays only a minor role. At most, planning of settlement and transport structures that cause less greenhouse gas emissions are possible strategies. This is of importance mainly for regional planning due to the given task of steering the main settlement structures. This may include spatial order categories, a central place system and development taxes taking care of concentrated development to support public transport networks and minimising distances between residential, recreation and working areas.

4.1.2 Nonstructural mitigation (a): reducing hazard impacts

Reducing hazard impacts has to be understood as a task for the responsible sectoral planning division that has appropriate instruments and the necessary knowledge. Nevertheless, regional planning can function as a supporting actor in this field of action (shown by the example of river floods in Table 1).

The following measures, carried out by the water management authorities, should be supported by appropriate designations in the regional plan to bind effects regarding municipalities and other sectoral planning divisions:

– Protection of existing retention areas (to maintain protective features of the natural environment that absorb or reduce hazard impacts),
– Extension of retention areas.

4.1.3 Nonstructural mitigation (b): reducing damage potential

Avoiding hazardous areas is the key task for spatial planning, especially at the regional level. The most important element consists of settlement re-

Table 1. Contribution of spatial-oriented planning and supporting instruments to risk management strategies. Source: Schmidt-Thomé 2005.

Risk management strategy	A. Regional planning	B. Local land-use planning	C. Sectoral planning	D. Supporting instruments
1. Prevention oriented mitigation	E.g. planning, settlement and transport structures that cause less greenhouse gas emissions	Supporting the use of regenerative energies	Strategies for reducing greenhouse gas emissions (e.g. transport structures)	Kyoto protocol; strategies for reducing greenhouse gas emissions; tax system
2. Nonstructural mitigation (a): reducing hazard impacts	Maintenance of protective features of the natural environment that absorb or reduce hazard impacts (retention areas, sand dunes)	Local rain-water infiltration	Flood protection plans; coastal protection plans; reforestation; adapted land cultivation	Interregional co-operation; economic instruments; information management
3. Nonstructural mitigation (b): reducing damage potential	Designations in regional plans like flood hazard areas	Zoning instruments	Adequate allocation of threatened infrastructure.	
4. Structural mitigation	Secure the availability of space for protective infrastructure	Prevention measures as a part of building permissions	Engineering design, Protective infrastructure (shoreline dams)	
5. Reaction: preparedness, response, recovery	–	Rebuilding planning	Emergency plans, e.g. SEVESO II safety report	Information and training to support public awareness and emergency management;

strictions by means of “priority zones” due to the given damage potential within highly populated areas. The designation of priority zones allows regional planning to keep hazardous areas free of competing demands. The regional level, under these stipulations, can directly control land-use decisions on a local level. With “reserve zones”, it is possible to improve awareness for appropriate judgement in local land-use decisions. Direct protection of these areas is not possible within regional planning, but it is possible within several sectoral planning divisions.

However, the concept of setting up priority zones until now has been oriented only towards single hazards like floods. A multi-hazard approach seems to be more suitable because it takes all spatially relevant hazards that might threaten a certain area into consideration.

In this context, the space-type concept might be able to fulfil these demands. The space-type concept is valid for Member States with institutionalised regional planning that includes legally binding regional plans or other forms of binding effects (e.g. Austria, Belgium, Denmark, Finland, Germany, Italy, Luxembourg, Netherlands, Spain, Sweden). The space-type concept is designed to prohibit and/or restrict settlement within hazardous areas. Thus, further additional damage potentials can be prevented.

– *Risk priority zones:* Exclusion of all uses, which are inconsistent with the priority function. Priority in these terms means that there is a land-use priority for a certain hazard or in other words, because of the possible occurrence of (a) certain hazard(s), no other form of land-use will be allowed. This means a strict settlement prohibition in threatened areas that is binding for local land-use planning as well as other planning divisions (e.g. transport planning etc.).
– *Risk reserve zones:* Settlement restrictions, consideration of given threats through building protection or exclusion of especially threatened (e.g. schools, hospitals) and hazardous (e.g. chemical plants) facilities.

The basis for these binding designations should be suitable hazard and risk maps. A system has already been implemented in Switzerland (Baumann & Haering 2000) and partly in Germany. However, this concept is primarily single hazard oriented, whereas spatial planning should be spatially-oriented. Hence, a further development for fulfilling a multi-hazard approach would be desirable on the basis of aggregated risk maps, which are based on the specific risk situation in a region (see Chapter 8 – Integrated risk assessment of multi-hazards). For this purpose, the Delphi method is an appropriate tool for the weighting of hazards. It was applied in the case study regions (see Chapter 10 – Case studies).

The main idea of the multi-hazard, *spatial-oriented concept* is based on the given interrelations between the several hazards and the interaction with the spatial structures (settlement, transport network etc.). According to the classification of regional planning, it is also valid for countries with legally binding regional plans or other forms of binding effects.

– *Risk priority zones:* Similar to the aforementioned space-type concept, the spatial oriented concept deals with settlement restrictions. Those areas identified as high-risk areas, threatened by a single hazard and/or a combination of different hazards that are strongly interlinked (e.g. earthquakes and large dams) should be designated as risk priority zones. For this purpose, a normative decision about the highest acceptable risk has to be done. Within those zones, which cross this boundary of acceptance, any settlement should be prohibited that would increase the present damage potential.
– *Risk suitability zones:* In contrast, risk suitability zones could be designated. This type is characterised by a below average risk level (e.g. low population density, absence of certain natural hazards like earthquakes etc.). Thus, those areas are principally suitable for the allocation of risky infrastructure, which is fragile on the one hand and/or could be dangerous for its surroundings if a disaster occurs (e.g. nuclear power plants).

This has to be carried out by regional planning authorities and regulated in a legally binding regional plan.

4.1.4 Structural mitigation

Similar to the reduction of hazard impacts, structural mitigation has to be understood as a task for the responsible sectoral planning divisions. Regional planning functions as a supporting actor in this field of action (shown again by the example of river floods):

– Allocation of new detention ponds (to improve the storage capacity),
– Relocation of dams or dikes.

In both cases, the protection of potentially suitable areas for those measures can be described as tasks for regional planning to avoid functions or facilities that might hinder the planned infrastructure.

4.1.5 Reaction: preparedness, response, recovery

Not relevant for the regional level due to the necessary concrete scale of such instruments that act primarily on a local level and below (single facilities).

4.2 Local land-use planning

4.2.1 Prevention oriented mitigation

In this context, local land-use planning plays only a very modest role due to the limitation on local affairs. However, land-use planning can act with supporting instruments, for example, by indirectly pushing the use of regenerative energies to reduce the emission of climatic relevant fossil fuels.

4.2.2 Nonstructural mitigation (a): reducing hazard impacts

Although the different sectoral planning divisions are the most important actors in this field, local land-use planning is able to support these actions. The more the impact can be limited to local areas, the greater is the potential influence of local activities.

Especially when regarding the contribution of settlement areas to surface run-off, the support of local rainwater infiltration activities has to be taken into consideration. In this way, local flash floods could be managed better by means of local activities that are the responsibility of the municipalities. Another possibility for local influence is the example of avalanches. Local reforestation activities may help to avoid avalanches.

4.2.3 Nonstructural mitigation (b): reducing damage potential

Zoning instruments: Hazard maps with a scale of about 1:2,000 – 1:10,000 are necessary for the enforcement of restrictions of land use at the municipal land use planning level. However, there are several possible types of zoning related instruments that might be able to improve non-structural mitigation, as discussed in the table below:

Table 2. Possibilities of the presentation of natural hazards within a local land use plan. Source: based on Böhm et al. 2002, p. 61.

	Co-ordinated zoning in general land use plan	**Specific hazard zones map in general land use plan with direct binding character**	**Independent map without a direct binding character to landowners**
Description	Consideration of the hazard areas during the compiling or the review of the local land use plan by the suitable allocation of types of land use and intensity.	The hazard zones are displayed as a separate map, which has a direct effect on land ownership rights – property owners have the right to object to the hazard zone classification shown. (Hazard zones as determined content).	Definition of hazard zones within the scope of expert planning ("hazard zone plan") – objections may be raised to decisions that are made on the basis. (Hazard zones as notification content).
Advantages	At the local level, no new instruments are necessary.	The hazard can be considered in a uniform manner for the complete local planning area. The definitions of the hazard zones can be applied directly in building approval procedures.	A simple alteration of a hazard zone plan is possible. Restrictions can be made according to the latestinformation. The administrative expenditure is low. Suitable for a cooperative strategy aimed at influencing existing building structures by means of individual building protection.
Disadvantages	Land-use plans only contain information about hazard areas when a special reference is made. An alteration of the danger situation means that the zone plan must be adapted accordingly.	An alteration of the danger situation means that the complete zone plan has to be adapted accordingly. For legally binding effects, a very carefully and exact mapping is needed.	No effectiveness in case of unwillingness of private stakeholders to participate.

4.2.4 Structural mitigation

Structural mitigation on a local level can primarily be understood as a task for building permissions aiming at special obligations to protect buildings or other facilities against potential hazard impacts (like flooding, avalanches, high wind speed, earthquakes etc.). Keeping in mind that building regulations often are under the responsibility of special state authorities, urban land-use planning offers the possibility for the municipality to influence building permissions.

For that purpose, the preparatory land-use plan should first designate potentially hazardous zones. Based on this information, it would be useful to integrate special obligations within a legally binding land-use plan aimed at the protection of buildings that might be developed within threatened areas. This could mean that any kind of subterranean or basement rooms are prohibited or an obligation for a strengthened outside wall that might be affected by avalanches.

4.2.5 Reaction: preparedness, response, recovery

Whereas mitigation aims at long-term preventive activities, reaction is a short-term activity immediately before or after a disaster occurs. Due to the fact that spatial planning is a long-term, future oriented activity, local land-use planning cannot be seen as a key actor. Reaction is primarily a task for the emergency response units. Nevertheless, two elements can be identified, where local land-use planning plays a decisive role:

1. The necessary integration of emergency response related interests within settlement and infrastructure activities: A residential area as well as an industrial facility must be reachable in an appropriate time by response units. In addition, in case of the allocation of emergency response stations, land-use planning has to take into consideration potential hazard impacts as well as suitable attainability by the different transport modals.
2. Urban land-use planning can be understood as a key actor in case of recovery activities after a disaster has occurred. The necessary rebuilding of houses and infrastructure has to be coordinated by planning that is ideally oriented on key risk management principles like avoiding hazardous areas.

5 CONCLUSIONS

In this volume, the general relationship between spatial planning and dealing with hazards was discussed, in particular the spatial planning response towards natural and technological hazards. The major findings are:

– A spatial perspective of hazards and risks requires a multi-hazard approach.
– The role of spatial planning is mainly related to risk management and not to risk assessment.
– Spatial planning can play an important role in the management of risks and at the same time, it is only one of many actors within a risk management process.
– Spatial planning already has instruments of direct and supporting character for the mitigation of risks; however, these instruments can be complemented and further developed.

These findings have shown that the response of spatial planning to threatening natural and technological hazards has to be seen as one of many actions that must to be taken within a region or a municipality. The involvement and cooperation of different public and private actors and comprehensive planning activities is required for a successful risk mitigation process.

However, spatial planning is just one of many actors but it plays a decisive role because only by spatial planning the future use of land can be guided.

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REGIONAL MULTI-RISK REVIEW, HAZARD WEIGHTING AND SPATIAL PLANNING RESPONSE TO RISK – RESULTS FROM EUROPEAN CASE STUDIES

by
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Olfert, A. Greiving, S. & Batista, M. J. 2006. Regional multi-risk review, hazard weighting and spatial planning response to risk – Results from European case studies. Natural and technological hazards and risks affecting the spatial development of European regions. *Geological Survey of Finland, Special Paper 42,* 125–151, 7 figures, 20 tables.

The presence of multiple natural and technological risks in an area is typical for most European regions. However, systematic consideration of multiple risks by spatial planning remains a major challenge. Within the scope of the ESPON Hazards project, a method for (multi-) risk review at regional level was tested, which combines easily available indicators for hazards and vulnerability. As a result, regional risk profiles are derived for four case study regions, providing indicative information for spatial planning at regional level. As part of the risk review, multiple hazards are weighted by expert panels using the Delphi Method. The Delphi Method has proved an appropriate and easily applicable method for deriving consensus between experts regarding the weighting of hazards for planning purposes in multi-risk situations. Weighting by different expert panels has confirmed that results partly depend on subjective risk perception of the participating experts. Methodological modifications in the case studies show that the scale of risk review and the set of indicators used can have a significant impact on the expressiveness of results. Detailed results from the Dresden Region and Centre Region of Portugal are presented.

Key words: natural hazards, technological hazards, risk assessment, spatial planning, weighting case studies, Germany, Portugal

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1 APPLIED METHODS AND SUMMARY OF FINDINGS

1.1 Introduction – Case studies within ESPON Hazards

Risk management has long been recognised as an important task of spatial planning (Greiving 2003, Karl and Pohl 2003) and is also assigned high importance in the European Spatial Development Perspective paper (CEC 1999, § 142).

> *Spatial planning at suitable government and administrative levels can play a decisive role… in the protection of humans and resources against natural disasters. In decisions concerning territorial development, potential risks – such as floods; fires; earthquakes; landslides; erosion; mudflows; and avalanches and the expansion of arid zones should be considered. In dealing with risks, it is important, in particular, to take the regional and trans-national dimensions into account.*

As a result, the spatial planning response as part of the overall risk management is a special research interest. In the ESPON Hazards project, case studies are conducted with the aim of supplying practice-level information into the EU-wide approach of the project. The investigation in case study areas provides information for the development of indicators and methods and for testing their applicability and limitations in practice. As well, case studies allow for detailed investigations including document reviews and expert interviews (e.g. in spatial planning administrations) to highlight specific aspects of regional hazards, vulnerability, coping strategies, risk awareness, official response or administrative capacity and other issues. On the one hand, this is important for methodological advancement, which can form the basis for systematic consideration of hazards and risks in spatial planning as a first step towards comprehensive risk management. On the other hand, findings uncovering planning reality lead towards specific recommendations for future development of risk management by spatial planning in Europe. The reference level chosen for case study investigations is the NUTS level III.

In total, four case studies are completed to extract information for different parts and phases of the ESPON Hazards project, comprising the Dresden Region (D), the Centre Region of Portugal (P), the Region of Itä-Uusimaa (Fi), and the Ruhr District (D). The main objectives of the case studies is the screening of spatial planning responses to issues of risk management and the development and testing of methodologies for regional risk review.

In the following, methodological approaches and results of the case study investigations are presented and discussed. First, a Strengths-Weaknesses-Opportunities-Threats (SWOT) based review will give a brief summary of the reality of spatial planning response to natural and technological risks in the case study areas. Second, the application of the Delphi method will be described and discussed. It will be shown that with the use of the Delphi method coordinated results can be achieved as a basis for systematic consideration of multiple risks in spatial planning. Third, a simplified method will be presented which allows for the derivation of an indicative inner-regional risk profiles depicting potential hotspots for risk management.

Finally, detailed results are presented for the case studies Dresden Region and the Centre Region of Portugal. The remaining two case studies are documented in the ESPON Hazards Final Report (Schmidt-Thomé).

1.2 SWOT-based review of the spatial planning response

The spatial planning response is reviewed in cooperation with regional planning authorities and mainly by document analysis and interviews with stakeholders of regional planning. By these investigations, light is shed into selected aspects of existing regional planning related to risk management. The SWOT-based review summarises main features with regard to the spatial planning reality of response to risk.

The case study areas show different planning responses to risks. However, certain characteristics seem to be generic. While planning systems generally offer effective frameworks for spatial planning, the consideration of risks is systematically underdeveloped. All case studies report only selected treatment of hazards, with rudimentary risk related planning. Methodological deficiencies and data gaps offer only a limited potential for risk assessment and thus prevent the systematic integration of risk management aspects into spatial planning.

The availability of implementation tools and controlling mechanisms seems to be developed differently in the planning systems. The settlement of regional planning at various administrative levels and its diverse legal backing entails different coordinating and enforcement power of regional planning. Public participation at the operational (local) level of spatial planning may play an important role for the acceptance of spatial planning.

The main opportunities lie in the partially growing sensitivity to risk and in the emerging risk management approaches in practice. Established administrative capacity and effective implementation of European regulations pave the way for a European-wide introduction of systematic (multi-) risk management in spatial planning. However, growing sensitivity and methodological advancements may not be effective if risk management in spatial planning is not settled upon a systematic approach that considers all relevant hazards and if insufficient competences, capacities and resources for their implementation and controlling are allocated to stakeholders of regional planning.

Table 1. SWOT-based review of regional planning response in case study areas.

	Strengths	Weaknesses	Opportunities	Threats
Region of Dresden (applies likewise for the Ruhr District)	• Well developed hierarchical planning system and planning culture • Sound legislative planning background • Clearly distributed competencies • Various spatial planning tools available at different levels • Area-wide spatial planning at different levels • Hazard prevention and mitigation included in various legal acts • Well developed control mechanisms integral to plan development • Acceptance of once approved spatial planning regulations	• Missing systematic consideration of risk in spatial planning • Missing requirements for integration of risk issues in spatial planning • Widespread risk related regulations • Selective treatment of hazards • Missing consideration of vulnerability issues • Missing data base for assessment of hazards and vulnerability • Missing practice of systematic and comprehensive risk management	• Growing sensitiveness to risk issues • Developing risk management approach with regards to floods • Availability of approved spatial planning instruments for development control, applicable to risk issues • Well developed administrative commitment • Effective implementation of European regulations	• Limitation of risk management approach to most present risks, omitting systematic multi-risk thinking • Failing to establish sufficient administrative capacity for risk related planning • Failing to establish sufficient legislative and political backing for risk related development control
Centre Region of Portugal	• Planning system developed at different levels • Regional planning backed by national legislation • Good legislative basis for flood risk management • Existing data base for flood risk management • Emergency plans developed at different levels and hazards	• Missing area-wide strategic plans • Limited binding character of regional plans • Missing risk documentation for planning issues • Missing systematic risk assessment • Missing systematic risk management	• Central planning level (NUTS II) allows balance of local interests in the scope of risk management • Developing risk management approaches (e.g. floods, forest fires, uranium mining)	• Failing to establish systematic risk management approach covering all risks • Limitation of advancement of risk management approach to selected hazards
Region of Itä-Uusimaa	• Well developed hierarchical planning system and planning culture • Sound legislative planning background • Clearly distributed competencies • Area-wide spatial planning at different levels	• Missing systematic consideration of risk in spatial planning • Widespread risk related regulations • Missing data base for assessment of hazards and vulnerability • Missing systematic and comprehensive risk management • Missing data base for risk evaluation • Limited binding character of regional plans	• Well developed spatial planning cooperation between municipalities • Well established public participation in spatial planning • Effective implementation of European regulations	• Failing to establish systematic risk management approach covering all risks

1.3 Applying the Delphi-method to the inner-regional weighting of hazards

1.3.1 Background

The importance of risk management is underlined by many international (IDNDR, Plate et al.1993, ISDR 2004), supranational (European research projects, EC structural funds) as well as national and regional activities developed and supported in the last years. Regional risk management in most cases faces the problem of multiple hazards. Multi-hazard cases can be described as settings where a multitude of hazards need to be included in the risk management of a certain area. Therefore, in order to allow for a consistent regional planning response, a multi-risk perspective is indispensable that considers the *entirety of spatial planning relevant hazards* and which integrates all responsible stakeholders in the region. The latter are typically spatial planning authorities at various administrative levels (regional planning, comprehensive land use planning), insurance and re-insurance companies, emergency response managers and other.

Whenever a multitude of hazards has to be considered in risk management, the question of weighting is raised. Weighting of hazards or risks can be accomplished by deriving weighting factors empirically, commonly based on loss data (damages) from historic events (by using insurance data such as Munich Re 2000, 2004). Nonetheless, this procedure would only cover a part of the issue. First, rare events (hazards) can easily be overlooked if no event has been recorded in the considered period. Second, loss data in general are not necessarily complete and may leave large data gaps. Third monetary loss data only cover monetary values whereas other (often intangible) aspects of loss like psychological stress would remain unconsidered (cf. Penning-Rowsell et al. 2000 and other). Finally, the exclusive consideration of loss data neglects differences in the perception of risk. But, beside the impartial risk analysis, 'risk' is also influenced by societally determined values such as risk perception (cf. Plate 1999) or risk aversion (PLANAT 2000), which can vary considerably between individuals and societies.

Thus, weighting of risks should also consider the 'subjective factor' of risk perception by going beyond factual information. This is possible through the use of feed back methods such as the Delphi method as a tool to generate weighting factors in multi-hazard cases that are relevant in the context of spatial planning (cf. Hollenstein 1997, p. 82ff, Lass et al. 1998, p. 23). The Delphi method was adapted for the specific use of multi-hazard weighting and tested several times in the four case study areas. In this application, the Delphi method should be seen as an assuming and embedded methodological tool for deriving weighting factors for the assessment of the overall risk of a certain area. For the application of results, a quantitative method is needed that uses the weighting factors in addition to pre-existing impartial information (see 1.4).

Furthermore, the derivation of weighting factors can have several advantages:

- Weighting can produce a common understanding of the severity of hazards compared to each other as part of risk assessment and as a basis for risk mitigation in spatial planning.
- Purposeful variation of weighting factors can be used for simulating different risk profiles depending on different conditions and including risk perception. This can be used for the development of scenarios for risk management.
- Regular iteration of weighting can allow the surveillance of the development of risk perception and thus illustrate changes over time.

1.3.2 Delphi as a weighting method in uncertain cases

The Delphi method is a study method that generates ideas and facilitates consensus among individuals with special knowledge in a certain field of interest. Unlike survey research, which requires random samples representing all parts of the population, for a Delphi study individuals are carefully selected, who have the knowledge needed for the analysis of a specific problem. The method is typically applied with mono-dimensional, uncertain issues which cannot be confirmed by impartial information. Developed in the 1960ies (Helmer 1966), the Delphi method has become widely accepted over the past decades, which becomes manifest in a broad range of applications by institutions, government departments and in research (cf. Turoff and Linstone 1975, Cooke 1991, Hollenstein 1997, Scholles 2001).

The method's original attitude is the investigation of opinions and ratings from different experts without necessarily establishing face to face contact and thus avoiding disadvantages of direct interaction such as communication barriers between individuals with different attitudes or positions, the dominance of key persons, travel and meeting costs and other aspects.

The Delphi Method is based on a structured process for collecting and synthesising knowledge from a group of experts through iterative and anonymous investigation of opinions by means of questionnaires accompanied by controlled opinion feedback (EVALSED 2003). The feedback is provided to encourage the recasting of individual opinions in the light of the summary of opinions given (for example the average or median of estimation or other statistical measures). The procedure is repeated several times. The goal is to reach convergence of opinions to produce an applicable result. Figure 1 shows an idealised convergence process. Due to the usually high degree of uncertainty of investigated issues, convergence may not follow a linear path as suggested. Particularly from the first to second repeat experts may more or less fundamentally recast their initial estimation.

The method has been used in hazard related investigations in the past. Deyle et al. (1998, p. 122) used it for the evaluation of hazard assessment in land use planning and management. Other applications were run to predict future trends in safety management (Adams 2001, p. 26) and food safety (Henson 1997, p. 195). Joel Goodmen (Turoff and Linstone 1975, p. 93) included hazard related aspects when conducting a policy-type Delphi on coastal zone development. However, few papers show a close relationship to the topic of weighting multiple hazards. Probably the most relevant investigations for the present topic were realised by Karlsson and Larsson (2000) using the Delphi method for the development of a fire risk index and Lass et al. (1998) who investigated the risk distribution for Germany. Karlsson and Larsson acquired weights and grades in numerical format regarding several so-called risk parameters. Lass et al. asked for a distribution of percentages for a selected number of risks. The latter applications also paved the way for generating consensus numerically.

In the first instance, the method is useful for subjects with a high level of uncertainty. This fully applies to risk assessment. While frequency, magnitude and consequences of occurring hazards are uncertain per se, each individual in a certain area can also be expected to perceive hazards and vulnerability differently. Therefore, in the public debate about risks the separation of objective and subjective notions such as risk analysis and risk perception (German Advisory Council on Global Change 2000, p. 38–39) is not possible. A wide variety of opinions exist regarding each single hazard or risk and possible options for mitigation. Therefore, each risk-related decision is subject to societal discourse. Thus, one goal achievable through the use of the Delphi method is the creation of a certain consensus among stakeholders with special knowledge on the issue as a basis for transparent risk related decision making.

However, in the past also criticism has been raised with regard to the Delphi method. The most important criticism refers to the often inappropriate application of the method rather than to the method in general. Application problems can embrace use with

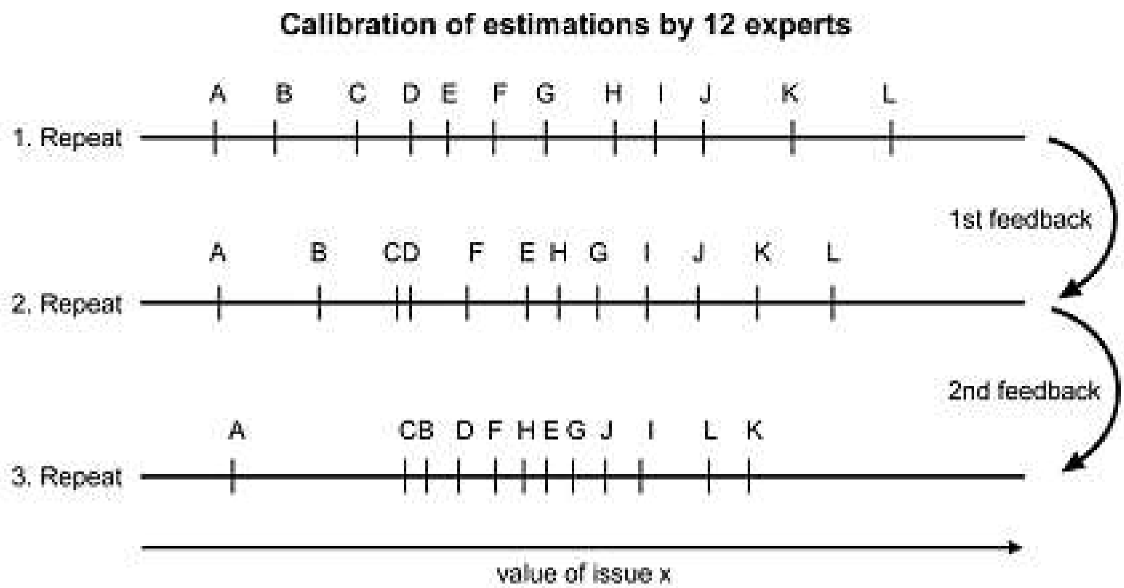

Fig. 1. Idealised process of calibration of individual estimations of experts (A-L) by use of the Delphi method (Hollenstein 1997, p. 83).

unsuitable issues (not uncertain or too complex), the integration of unqualified or over biased experts, mistakes in the implementation process (incomplete information, inappropriate feedback), or the over-interpretation of results. Thus, the application of the Delphi method should be undertaken with due awareness of these and other potential sources of distortion.

For weighting, the following procedure has been followed in the case studies:

1 Identification of the weighting question
2 Choice and definition of hazards and preparation of the analysis tool
3 Choice of experts
4 Carrying out the Delphi survey
5 Analysis of results and success control

Weighting results were used for the generation of a regional risk profile through the use of the simplified risk assessment method presented in chapter 1.4.

The matter of weighting is the expert's professional and personal view on the relative importance of the selected hazards in the region. The central question behind the weighting was:

How hazardous is one hazard compared with another in the region?

'Hazardous' means a hazard's potential to cause harm under average regional conditions. First, this question requests the expert's knowledge on multiple hazards. Second, it requires that experts set aside possible bias towards one certain hazard, but try to oversee the general situation in the region. Third, and most importantly, it appeals to the experts' perception of *hazardousness* of the hazards. Though attached to hazards, the question also appeals to personal perception of risk as connected to the hazard. Thus, the question is asked on the borderline between hazard and risk.

1.4 Method for inner-regional risk review

1.4.1 Background

Spatial planning, due to its notion of coordination (Faludi 2003), is an indispensable partner of risk management. In particular, management of spatially relevant risks is unthinkable without spatial planning (Greiving 2003). Nevertheless, the review of spatial planning reality has unveiled considerable deficits in spatial planning with regard to risks. While spatial planning is generally well established and applicable instruments already exist, there often remains a conceptual lack – if at all, risks are considered only selectively. Systematic consideration of hazards and risks in spatial planning virtually does not exist (cf. Heidland 2003). The reasons for this may be a certain unawareness of the relevance of hazards for spatial development, but also methodological deficits and the lack of data can both considerably constrict the integration of hazards in spatial planning.

Whatever the reasons may be, the enormous increase of losses (Munich Re 2004) even from average events urges action at all levels. Methodological advancement in the area of detailed risk assessment has been identified as an issue of major interest in research. However, efforts are needed to develop approaches ready for application in spatial and especially in regional planning, thus giving the stakeholders the capacity to act. The requirements for this are not only issues of regional risk management. Also, policy change at a European level may urge for action in near future, e.g. by coupling structure funds to issues of risk mitigation (cf. David 2004, p. 155).

As a solution for the review of regional risk distribution, the generation of a simple risk profile is proposed and tested in the case study areas. It is based on a multi-risk approach considering all potentially relevant (spatial) risks in an area and applies relative weighting factors derived by the use of the Delphi method (see above). By refining hazard information with regional vulnerability data, different levels of refinement are possible, indicating areas with different degrees of risk aggregation.

1.4.2 The method

The method for generating inner-regional risk profiles is based on the risk concept applied by ESPON Hazards, which sees risk as the coincidence of hazard and vulnerability (cf. Blaikie 1994, Helm 1996, Kron 2002). Both, hazard and vulnerability are represented by certain indicators (Figure 2). In the following, the method is described as a sequence of steps leading to a certain risk class.

1. *Selection of indicators representing factors of risk*
In this paper, 'hazard' is represented by the *haz-*

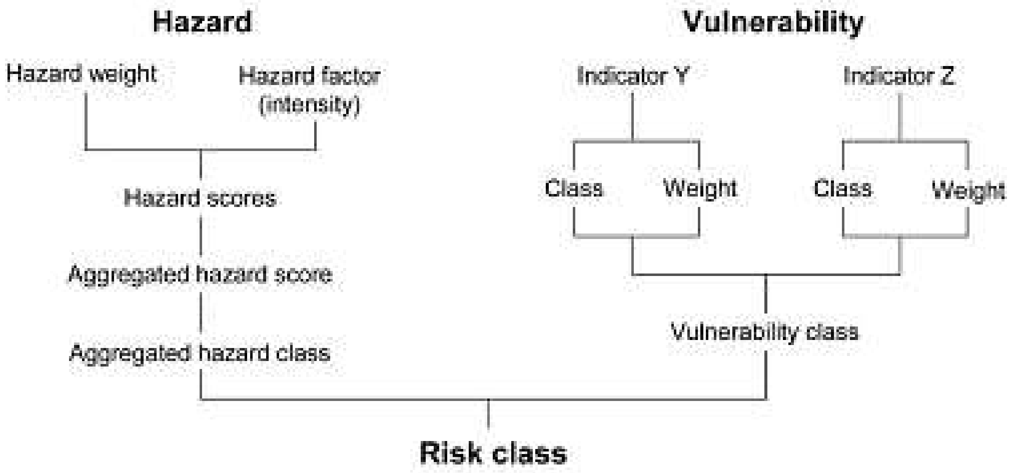

Fig. 2. Simplified procedure of derivation of risk classes.

ard frequency. 'Vulnerability' is represented by the indicators *GDP per capita* and *population density*. As indicated in the right column of Figure 2, vulnerability indicators can be manifold. They are also represented differently in the case studies. The approach is generally open to more indicators than used.

2. *Preparation of relative weights assigned by the panel of experts to each single hazard*

Hazards and vulnerability indicators are considered weighted. Hazard weights are derived through the use of the Delphi method. Vulnerability indicators were also partially weighted applying the Delphi method.

3. *Derivation of the hazard factor*

The *hazard factor* is used to substantiate weights assigned in the first step. It is derived from the regional intensity class of each hazard (Table 2). Different methods for hazard assessment exist in practice. In the ESPON Hazards project, hazard, intensity classes were established by combining the statistical frequency of the occurrence of the hazard and the magnitude of the events. The hazard factor is used as a multiplier for establishing the weighted hazard score.

Table 2. Hazard intensity classes and the corresponding hazard factor.

Hazard intensity class	Hazard factor
1	0.2
2	0.4
3	0.6
4	0.8
5	1

4. *Derivation and aggregation of the weighted hazard scores*

The *weighted hazard score* is obtained through the combination of single hazard weights and the assumed hazard intensity in the reference area (e.g. NUTS level III). However, reliable hazard information may not be available for every hazard. Weighting factors for each hazard and hazard factors obtained from the potential hazard intensity are multiplied to obtain the individual *weighted hazard score* for each hazard (see also Table 3):

weighted hazard score
=
individual hazard weight * single hazard factor

By adding the individual hazard scores, the aggregated *weighted hazard score* of the region is obtained. The expected outcome (sum of all hazards scores) delivers a figure between 20% (in case that all hazard intensities are class 1) and 100% in case

Table 3. Establishing and aggregating weighted hazard scores.

Hazard (exp. from Dresden region)	**Weight**	**Hazard intensity class***	**Hazard factor**	**Weighted hazard score**
Volcanic eruptions	0.2	1	0.2	0.0
Floods	24.8	3	0.6	14.9
Landslides/Avalanches	2.8	1	0.2	0.6
Earthquakes	0.4	1	0.2	0.1
(…)	(…)	(…)	(…)	(23.0)
sum	**100**			**38.6**

that all hazards are in intensity class 5. As an example, in the Dresden region the scores sum up to 38,6 (Table 3).

5. *Classifying the aggregated hazard scores*

To obtain the aggregated hazard class, the calculated, aggregated weighted hazard score is classified on the basis of a 5 class scale (Table 4), starting with 20 as the lowest possible score.

6. *Derivation of the vulnerability class*

The differentiation between the sub-regions is based on vulnerability information at the sub-regional level and weighted as a result of the weighting procedure is important. Vulnerability is represented by the *vulnerability class* for each area of reference:

Vulnerability class
=
Indicator Y * indicator weight + Indicator Z * indicator weight …

Table 5 shows the calculation of the vulnerability class for two sub-units of the Dresden Region using the indicators 'GDP per capita' and 'Population density'. The result is a weighted vulnerability class for each NUTS 3 region within the case study area.

7. *Derivation of risk classes*

The derivation of risk classes is the final step, which is accomplished through the matrix-based combination of the aggregated hazard class with the obtained vulnerability class (Table 6).

Regional risk profiles are drawn for the chosen areas of reference. The presented procedure allows for further refinement down to levels beyond NUTS III. Due to the limitations of existing data, in the case study areas the NUTS level III was chosen as the level of reference. Cases study areas show different examples. While the Itä-Uusimaa case study is restricted to one NUTS level III area, the Dresden Region and Centre Region of Portugal are comprised of several NUTS III regions and thus allows differentiation of sub-regions. Due to good data availability, the Centre Region of Portugal offers an example of further refinement of results to NUTS level IV, unveiling more detailed spatial patterns of the spatial risk distribution.

Table 4. Classification of the aggregated hazard class.

Aggregated hazard class	Aggregated hazard scores
1	20–35
2	> 35–50
3	> 50–65
4	> 65–80
5	> 80–100

Table 5. Derivation of vulnerability classes (example from Dresden Region).

NUTS level III Districts	**Population density** (55%)			**GDP per capita** (45%)			**Vulnerability class** pop. dens * GDP
	Value** (pers./km^2)	% (EU 15 average = 100)	**class**	value*	% (EU 15 average = 100)	**class**	Results (Weight 55 : 45)
Dresden Stadt	1.455	1.233	**V**	23.145	112	**III**	**IV**
Meißen	242	205	**IV**	16.149	78	**III**	**IV**

Table 6. Derivation of the regional risk profile through a combination of hazard and vulnerability.

Aggr. Hazard (class)	**Degree of vulnerability** (class) (example from Dresden Region) I	II	III	IV	V
I	2	3	4	5	6
II	3	4	5 Riesa-Großenhain Sächsische Schweiz Weißeritzkreis	6 Dresden Meißen	7
III	4	5	6	7	8
IV	5	6	7	8	9
V	6	7	8	9	10

2 THE DRESDEN REGION

2.1 Regional background

The Planning Region Oberes Elbtal / Osterzgebirge (Dresden Region) is one of five planning regions in Saxony. It is comprised of five sub-regions at the NUTS level III including the urban district of Dresden (City of Dresden), the District of Saxon Switzerland, the Weißeritz District, the District Meißen, and the District Riesa-Großenhain. The biggest share of the population (46%) and the highest population density (1455 persons/km^2) is in the City of Dresden (RPS 2004). In total, over 67% populate 'densely populated areas', a spatial category that is only assigned to 10 municipalities out of 87 in the region. The south of the region borders the Czech Republic.

Over the past 15 years, spatial patterns in the region have undergone considerable change, which is ongoing. The reason for the change is the transition from a centralised to a federal planning system with guaranteed self-government at the local level and major economic transitions, both induced by German Unification in 1990. Considerable economic transformation as well as loss and redistribution of population have taken place. Loss of population in the inner city and rural areas is accompanied by urban sprawl at the edge of urbanised areas.

The most important business branches in the region are information technology, engineering (including aviation, automotive industries), food processing, the glass and ceramics industry, paper industry as well as publishing and printing, which together make up about 80% of the employees in the manufacturing industries. Most industries are concentrated in and around the city of Dresden (Figure 3). As the capital of the Free State of Saxony, the City of Dresden also is an important centre of administrative employment.

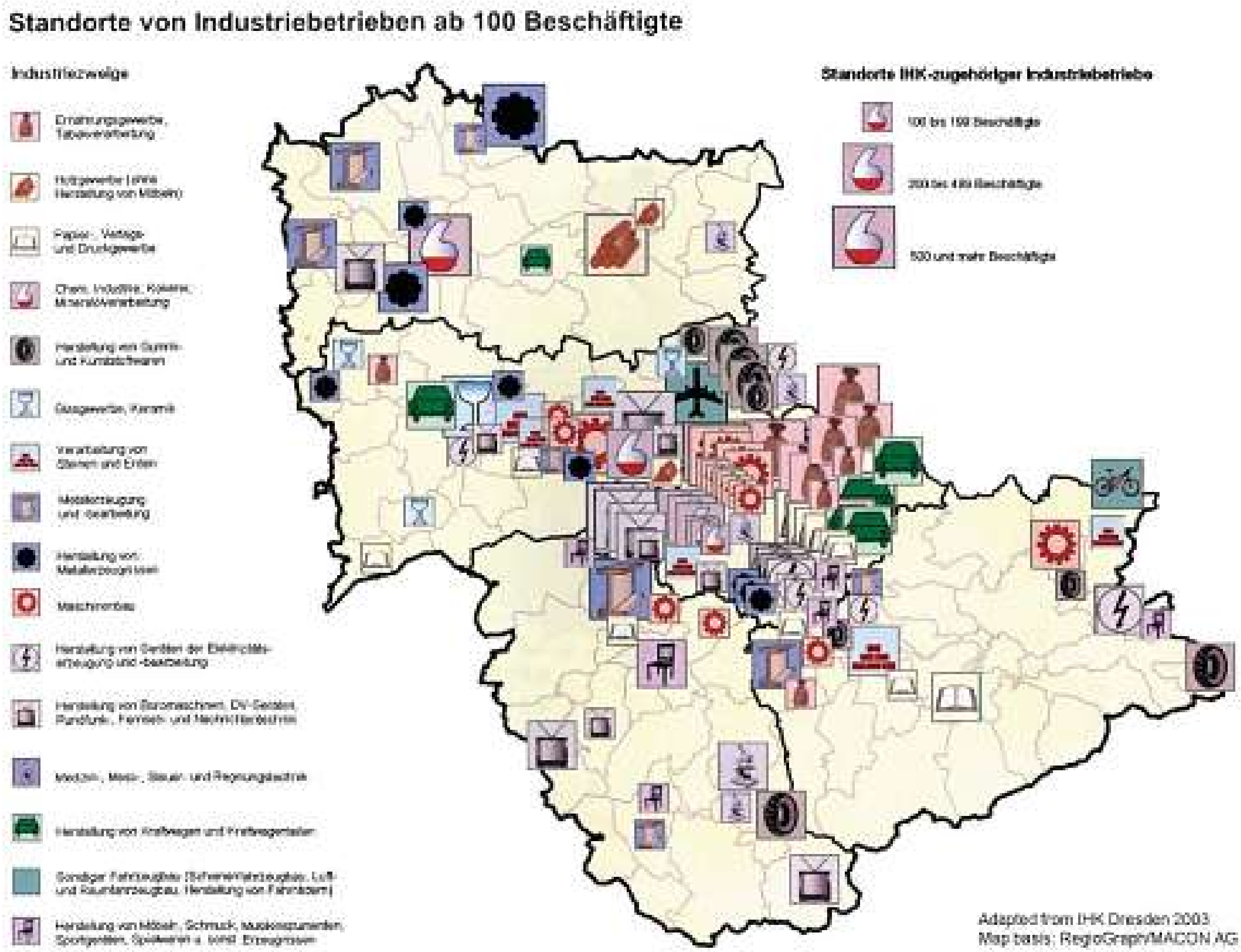

Fig. 3. Industrial plants in the Dresden Region with more than 100 employees (map: IHK Dresden 2003, p. 73).

Due to a polymorphic landscape, persisting industries, high population density in urban areas and the proximity of the region to other potential sources of hazards, various natural and technological hazards are evident in the Dresden region.

A special feature with relevance to hazards is the valley of the Elbe River, which, originating in the Czech Republic, flows through several towns of the region like Bad Schandau, Pirna, Dresden, Meißen, Riesa and Torgau. The discharge dynamic of the river Elbe is mainly influenced by precipitation and by the outlet from large dams in the Czech Republic.

Natural hazards

The most present natural hazards in the region are floods and windstorms. The region was hit heavily by the August 2002 flood that resulted from extreme precipitation in Saxony and the Czech Republic (Schanze 2002, DKKV 2003) and caused severe flash floods in the tributaries as well as an enormous slow rise flood along the Elbe River valley. Another known natural hazard refers to the special geological situation in the south of the planning region. Due to the steep relief in the sandstone area of Saxon Switzerland, collapses of rock formations and land slides occur regularly. However, while floods and windstorms affect large areas of the region, rock collapses and land slides are rather small events, which occur on a local level only. Therefore, these hazards have no significant relevance on a regional level.

Technological hazards

The Dresden Region is historically densely industrialised. Potential sources of technological hazards are single production plants of *chemical and manufacturing industries* that deal with hazardous substances and hazardous combinations of substances, the inland harbours along the Elbe river and the airport. In 1998, 344 industrial plants were registered under the German Emergency Ordinance (UBA 2000, p. 48).

In the past, coal and ore mining were also important in the region. Whereas most of the mining was completed decades ago, uranium mining had continued until early 1990s in two locations. Relicts of the mining activities are the not totally mapped and partly not totally known cavities (RPV 2001). From the past, no catastrophic collapses of cavities are known. Land subsidence hazards caused by past mining cavities have shown that these may have spatial importance but have not been sufficiently explored and documented. Only local subsidence areas in ancient mining locations are known. For the time being, no mapping of source areas or potentially exposed areas is available.

Other mining relicts are the countless waste heaps from non-ferrous metal mining (zinc, silver, bismuth, cobalt and nickel), mining and uranium mining as well as sites with deposits from uranium extraction plants (RPV 2001). The impacts of the uranium extraction plants have not yet been fully explored. However, conceivable hazard pathways such as direct radiation, excess radon exhalation, wind erosion of deposits and leachate into the ground water (SSK 1990) lead to the assumption that only creeping hazards can be expected which are not considered by the study.

There are no nuclear power plants in or close to the region. The nuclear physics department at the Research Centre Rossendorf is a single structure situated close to Dresden that deals with radioactive substances.

Taking into account the potential ‘hazard path’ along the Elbe river valley, chemical plants along the Elbe and Vltava rivers in Czech Republic are also relevant for the Dresden region. Several plants situated in the floodplains of the rivers have considerable amounts of hazardous substances potentially exposed to flood waters.

Small and large dams in the tributaries and the main valley of the Elbe River are a special technological feature in the mountainous part of the Dresden region. There are more than 3000 dams and weirs in the waters of Saxony, several hundreds of those in the planning region (LfL 2004). Several large dams create major impoundments of the Elbe and Vltava rivers in Czech Republic. The importance of this hazard was seen during the August 2002 flood when lives were endangered by the flood wave generated through the collapse of a retention basin, floods waves in virtually all rivers exceeded the storage capacities of dams and the operation of some large dams ran out of control.

2.2 Spatial planning and hazard mitigation

2.2.1 The spatial planning system and instruments

The German planning system is based on the *Constitution* (Basic Law 2002), which provides a general societal context as a framework for development and ensuring the so-called self governing right of municipalities (the lowest level is the administrative structure). Section 75 Nr. 4 of the constitution assigns the national level a so called 'framework competence' to set a framework for spatial planning in Germany. Nevertheless, spatial planning and development takes place at and is influenced by regulations from different administrative levels and is carried out by various institutions (Schmidt-Thomé 2005, Annex IIA). While municipalities physically implement the spatial planning and development, much regulation and coordination takes place at the regional levels.

A central feature of the planning system is the so-called subsidiarity principle. This means that decisions relevant to spatial development are passed "down" as far as sensibly possible to the subsequent levels. Based on this principle, spatial planning in Saxony takes place in a multiple-step approach:

– The federal government provides framework legislation and general spatial development guidelines and formulates aims and principles for spatial development.
– The Free State of Saxony (NUTS II) transmits federal requirements for spatial development into the Länder context, sets the larger spatial development framework legislation and provides statements on how the territory is to be developed. The Comprehensive Plan (CP) designates central places, main development and major transportation axes as well as areas of super-regional or federal interest.
– The actual regional planning in Saxony takes place at the planning regions level (covering several NUTS III areas). Here, the statements from the Länder level, especially those of the CP are specified in the Regional Plans (RP) and together serve as legally binding statements for municipal planning.
– Finally, municipalities (NUTS IV) are the operative level where planning and development activities are planned and implemented.

Various implementation strategies at the regional level and instruments of implementation at the local level support the materialisation of spatial planning (Table 7).

Table 7. Regional implementation strategies and local instruments.

Regional implementation strategies	Local instruments
– Regional (joint) land use plans – Regional Planning boards – Cooperation strategies – Public participation	– Landscape Plans – Preparatory land use plans – Preliminary binding land use plans – Priority areas – Reserve areas – Flood Zones

2.2.2 Hazard mitigation in regional planning practice

The German planning system at all planning levels requires the integration of various concerns. This is realised through the elaboration of sectoral plans. Whereas a large number of sectoral plans finally make up 'the spatial plan', no explicit 'risk' or 'hazard plan' exists. Rather, spatial planning integrates issues dealt with in different, often binding documents, such as (thematic) laws valid for various (potentially hazardous) issues like the Emissions Protection Law or the Federal Environment Law. These documents are usually not directly dedicated to risk mitigation, but often contain requirements on security issues and are to be considered in the course of approval procedures for spatially significant development projects. Due to the subsidiarity principle, most regulations are being implicitly integrated into spatial plans, and are thus not explicitly displayed.

Implicit hazard mitigation takes place, for instance, for droughts and storms or heavy precipitation by integrating these issues into spatial development recommendations. An example is the recommendation to change tree species combinations in certain forest areas to reduce the probability of drought, to increase the stability against wind storms and/or to reduce surface runoff. Permitting authorities also are bound to avoid new housing development in the very vicinity of a hazardous industrial plant and vice versa, but on a single case basis rather than a systematic risk reduction approach.

Therefore, the analysis of the regional planning documentation in Saxony may lead to the impression that very few elements of risk prevention are included. Indeed, in practice no systematic risk analysis, assessment or mitigation (cf. Plate 1999) is being performed by spatial planning authorities, which is also true for the Dresden Region. Consequently, no systematic information (like hazard maps, vulnerability maps, risk maps) about relevant risks is available. So far, selective hazard and risk identification takes place only in the field of environmental hazards (like soil erosion or deflation). While relevant for spatial planning action, these are also rather creeping hazards that do not show sudden or accidental appearance and are therefore not considered in this scope.

In practice, continuous cooperation exists between spatial planning authorities and sectoral authorities, which are in charge of phenomena related to hazards (like the State Institute for Environment and Geology). There are also instruments (see above) available for dealing with hazardous areas at different administrative levels. However, the issue largely relies on the initiative from spatial planning partners but lacks systematic basis.

For the case study region, the two relevant regional planning documents, the CP of Saxony and the Regional Plan of the Dresden Region, both hardly refer to hazards. If so, information is on a purely descriptive and qualitative basis.

The *Comprehensive Plan* traditionally contains only a few direct statements relating to hazard issues. Also, the aims of spatial development do not contain statements that could be interpreted as being related to risk prevention. The current CP (SMI 2003) recognises a particular call for action in the context of:

– Safe usability of former coal-mining areas (goals 3.3.7. – 3.3.9)
– Preventive protection of the drinking water resources (goal 4.3.1.)
– Preventive flood protection measures (principle 4.3.7, goals 4.3.8.–4.3.9.)
– Limitation of land use in ecologically sensitive areas (principle 4.1.3–4.1.4)
– Rehabilitation of former industrial areas for safe land use (principle 4.4.3.)
– Pronunciation of precautionary hazard prevention, especially flood protection, in terms of a sustainable development strategy (p. 108)

The current CP in this respect does not show considerable advancements compared to the previous CP (SMI 1994), which only referred to the following issues:

– Preventive protection of water resources usable for drinking water abstraction (so called Water Protection Areas, B-64)
– Hazard prevention in a location with a probability of landslides due to past surface coal mining (B-104)
– Hazard prevention in areas of past uranium mining where direct radiation may be exposed (B-104)
– Protection of the population against emission of noise, vibrations and air pollution (B-136)

Most of the statements are made from the perspective of the technical means of environmental protection rather than from a systematic risk management perspective. Also, the Regional Plan of the Dresden Region contains only scarce reference to spatially relevant hazards. Basically, these references are limited to general statements about flood protection as shown by Table 8.

The situation is starting to change with regard to the flood hazard. After the disastrous flood events in August 2002, the hazard maps are being prepared, sub-basin based flood protection plans are elaborated and legislature adapted. The new Environment Protection Law urges the delimitation of flood prone areas as a basis for spatial planning and development and defines restrictions on land uses (Hochwasser-

Table 8. Direct and indirect statements related to flood protection in the RP for the Dresden region.

Instrument	Cartographic display	Summary / aim or principle
Priority areas for flood protection	Map of spatial uses1:100000 Symbol (usual retention capacities smaller and larger than 1 Mio m^3)	*Aim 4.4.6*: Completion of the system of flood retention structures in the Eastern Ore Mountains and in the Müglitz river valley. *Requirement 4.4.6*: Environmentally sound flood protection
Flood zones (assigned and planned)	Map Maintenance, Development and Restoration of the landscape 1:100000	*Principle 4.2.2.6*: Clearing and reopening of natural paddles along the Elbe river, allowing for ground protection in case of floods, etc.

schutzgesetz 2005). The process is supported by the newly issued Flood Protection Program of Saxony. Sectoral documents usable for the purpose of risk mitigation such as ‘flood hazard maps’ and ‘flood source area maps’ are being prepared that will cover the whole territory of Saxony.

For other hazards, hardly any information is available and usually no responsibilities can be traced. Thus, systematic consideration of risk issues takes place as early as with disaster mitigation, which is out of the competences of spatial planning (Table 9).

Table 9. Levels and instruments of disaster mitigation in Germany (Grünewald and Sündermann 2001).

		General	Flood related
Foundation of disaster-protection in German laws.		Basic Law, Civil protection lawLaws of the states (i.e. Disaster protection law)	Water management law Specific laws of the states
Responsibilities in disaster protection		Duty of the states Supported by the federation Districts and districtless cities as the local disaster-protection authority	Ministry of the Interior as the supreme disaster-protection authority;
Instruments and actors of disaster-protection	Disaster prevention	Disaster protection plans (districts, main cities) Plans for management and maintenance of flood prevention constructions and flood prediction	Flood-prevention plans (cities, districts);
	Disaster management	Volunteers, Aid organisations, Units of extended disaster response, Fire-fighters, Technical Aid (THW), if required: border police, customs, army	Additionally State Environmental Agency, volunteers, private companies

2.3 Exemplary Risk Review for the Case Study Region

2.3.1 Introduction

The inventory of risk reduction by spatial planning in Saxony shows that in excess of an existing elaborate internal weighing procedure, which is integral to permission practices, systematic risk analysis at regional level should build the basis for a systematic spatial planning response to risks. The spatial overlapping of various risks especially calls for a multi-risk approach based on existing data and considering expert knowledge. In the following, the above presented methods for weighting of hazards and for the generation of inner-regional risk profiles are tested.

For this methodological test, the Dresden Region is particularly promising due to extensive social and economic disparities between the five NUTS III sub-regions. Whereas the City of Dresden is a densely populated economic centre with over-regional importance, the surrounding sub-regions are characterised by low population density and a peripheral economic situation. However, resolution of existing indicator data has the potential for further refinement of results.

2.3.2 Choice of experts for the Delphi survey

As systematic risk assessment is still not developed, only few practitioners have extensive knowledge of natural and technological hazards with a good overview of the case study area. However, due to the presence of past events (see above), experts showed particular interest to constructively participate in the Delphi panel.

The method is applied with two discrete groups of seven experts from four resp. five different institutions. For the first expert group mainly planners and administrative experts dealing with planning and plan approval issues are considered. In the second expert group, scientific expertise in regional and hazard related phenomena is emphasised. Lacking the ‘perfect expert’, specialists are chosen that combined as much expertise as possible on the case study area and spatial planning with respect to hazard related phenomena and risk assessment. Experts from the second group range from specialised research institutes and public authorities to state ministries. Special relationship of experts to single hazards is avoided. Though professional homogeneity is a particularly important criterion of choice, a certain degree of heterogeneity in terms of personal attitude towards the topic could not be totally excluded.

2.3.3 Choice of hazards and vulnerability indicators for the Delphi survey

The used set of hazards includes twelve hazards (Table 10), which not all are necessarily relevant for the region. Behind this stands the expectation that irrelevant hazards would be scored zero by the panel. Two main indicators are chosen as proxy for economic damage potential to represent the regional vulnerability: 'Population density' and 'GDP per capita'.

2.3.4 Application of the Delphi Method

The Delphi inquiry in both expert groups is conducted through three rounds. Prior to the inquiry, the experts were informed about the background of the test and the attitude of the method used was explained. All experts were contacted personally by telephone to ensure that no questions remained open and to increase the personal commitment of the participants. The experts were asked to estimate (weight) the relevance of twelve hazards for the Dresden region as explained in chapter 1.3.2. A weighting has also been conducted for the vulnerability indicators. In the first round estimations are delivered uninfluenced. In round two and three, experts were acquainted with the mean result from the previous round.

2.3.5 Weighting the hazards

All proposed hazards received at least a very low consideration of relevance in both repeats (Table 10 and Table 11). The reason may be seen in the assumed relevance of distant events that may impact the region. However, it became apparent that most importance was attached to natural hazards (first/second repeat 79/75%) with floods (25/26%), extreme precipitation (16/16%) and storms (13/13%) at the top of the estimation (Table 11). Technological hazards in total received only 21/25% with industrial production plants (6/9%) on top.

Despite a purposefully different composition of expert groups, results derived from both expert groups are very close in terms of scores and dynamics of assessment through the rounds. Measuring the change in estimation from round 1 to round 3 in percent, the largest relative change was seen in the hazard estimations for volcanic eruptions and landslides/avalanches as well as for earthquakes and nuclear power plants (Table 10). These hazards, however, are at the same time the four lowest (absolutely) estimated hazards with given percentages be-

Table 10. Average estimations and their change in two expert groups.

Hazards		**Average estimation Expert group 1**			**Average estimation Expert group 2**			**Change in estimation** Round 3/ Round 1(%) Expert group 1	**Change in estimation** Round 3/ Round 1 (%) Expert group 2
		Round 1	**Round 2**	**Round 3**	**Round 1**	**Round 2**	**Round 3**		
Natural Hazards	Volcanic eruptions	0.3	0.2	**0.2**	0.0	0.0	**0.0**	**65.0**	–
	Floods	24.4	24.9	**24.8**	26.7	27.0	**26.0**	**101.5**	97.3
	Landslides/Avalanches	3.9	2.6	**2.8**	2.3	2.6	**2.2**	**72.0**	97.5
	Earthquakes	0.4	0.3	**0.4**	0.7	0.7	**0.7**	**83.1**	94.0
	Droughts	9.6	9.1	**9.1**	6.4	5.7	**6.1**	**95.1**	95.6
	Forest Fires	8.6	9.0	**9.2**	7.7	7.6	**7.7**	**106.6**	100.0
	Storms	12.9	13.6	**13.1**	11.3	11.4	**12.9**	**102.2**	113.9
	Extreme precipitation	14.6	14.9	**15.0**	14.3	14.6	**15.6**	**103.0**	109.0
	Extreme temperatures	4.0	4.0	**4.0**	4.0	4.1	**4.1**	**100.0**	103.6
Technological hazards	Nuclear power plants	1.7	2.0	**2.1**	2.1	1.3	**1.1**	**124.0**	53.3
	Production plants	5.8	5.7	**5.6**	8.9	9.7	**9.1**	**96.6**	102.7
	Waste deposits	4.1	3.9	**4.1**	5.3	5.8	**5.4**	**100.0**	102.7
	Marine/inland waterway transport	3.8	3.4	**3.5**	6.6	6.5	**6.3**	**92.6**	95.7
	Dams	6.0	6.5	**6.1**	3.7	3.0	**2.7**	**102.8**	73.1
	Sum	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**		

tween 0.2% and 2.8%. The relative changes in estimation for the other, higher ranked, natural and technological hazards changed only by a maximum of 6.6% (Forest fires) from Round 1 to Round 3.

The seemingly minor influence of several previous rounds on the final result, however, has to be seen in light of the *coordination process* induced by the use of the Delphi method. To evaluate the progress, the 'coefficient of variation' is used (Table 11). This measure relies on average estimations and the 'standard deviation' of single responses and shows a clear 'coordination effect' through the rounds. With the exception of the hazard 'extreme temperatures' in the first expert group, the coefficient constantly decreases through the rounds by 15% (volcanic eruptions) to over 50% (extreme precipitation).

2.3.6 Weighting vulnerability indicators

A widely agreed consensus is found among the experts in relation to the proposed vulnerability indicators 'Population density' and 'GDP per capita'. However, weighting results change more than in the case of hazards. Whereas the first expert group agrees on a weight distribution of 55% and 45%, the second expert group awards the indicators scores of 61% and 39% respectively (Table 12). It may be assumed, however, that the unexpected consensus in the first expert group was influenced by different pre-information. The first group was informed about the previously used weighting factors 50/50. Also, the variation of responses does not change through the inquiry. However, in the second expert group, the variation of responses began and ended about three times as high (Table 13).

Table 11. Measuring the coordination effect - the coefficient of variation.

Hazards		**Coefficient of variation Expert group 1**			**Coefficient of variation Expert group 2**		
		Round 1	**Round 2**	**Round 3**	**Round 1**	**Round 2**	**Round 3**
Natural Hazards	Volcanic eruptions	163.0	141.4	**139.6**	–	–	–
	Floods	62.1	52.5	**49.0**	65.6	36.7	**35.2**
	Landslides/Avalanches	97.6	64.0	**52.6**	86.5	38.0	**31.7**
	Earthquakes	100.3	122.2	**82.4**	105.8	68.3	**70.2**
	Droughts	38.0	27.8	**26.3**	112.1	89.1	**78.9**
	Forest Fires	39.1	30.8	**26.1**	50.6	46.3	**48.9**
	Storms	35.7	30.3	**27.4**	77.0	67.6	**55.1**
	Extreme precipitation	28.1	18.1	**13.3**	55.7	52.2	**45.4**
	Extreme temperatures	30.6	35.4	**35.4**	81.6	40.5	**38.0**
Technological hazards	Nuclear power plants	99.0	70.7	**62.1**	148.6	132.6	**128.1**
	Production plants	70.5	62.1	**51.4**	67.2	57.2	**54.4**
	Waste deposits	72.3	66.6	**57.2**	106.9	65.8	**48.6**
	Marine/inland waterway transport	48.0	45.4	**32.3**	79.0	54.9	**40.8**
	Dams	85.2	48.7	**53.1**	45.9	50.9	**46.2**

Table 12. Weighting of vulnerability indicators: average estimations and changes in estimation.

Indicators of vulnerability	**Average estimation Expert group 1**			**Average estimation Expert group 2**			**Change in estimation** Round 3/Round 1 (%) Expert group 1	**Change in estimation** Round 3/Round 1 (%) Expert group 2
	Round 1	**Round 2**	**Round 3**	**Round 1**	**Round 2**	**Round 3**		
Population density	54.3	54.7	55.3	59.3	61.9	61.1	**101.8**	**103.1**
GDP per capita	45.7	45.3	44.7	40.7	38.1	38.9	**97.8**	**95.4**
sum	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**		

Table 13. Weighting of vulnerability indicators: measuring the coordination effect, coefficient of variation.

Indicators of vulnerability	**Coefficient of variation Expert group 1**			**Coefficient of variation Expert group 2**		
	Round 1	**Round 2**	**Round 3**	**Round 1**	**Round 2**	**Round 3**
Population density	12.2	10.9	9.0	33.9	23.0	22.7
GDP per capita	14.5	13.1	11.2	49.3	37.3	35.7

In general, average estimations received from both groups did not substantially differentiate from each other. This may be taken as proof of the general suitability of the method.

2.3.7 Risk profile of the Dresden Region

By applying the ESPON Hazards approach, an aggregated hazard potential for the Dresden region is obtained that amounts to 38.6% (Table 14) of a potential maximum of 100%. This corresponds with aggregated hazard class II. Considering weighting factors of vulnerability indicators, the final vulnerability class is determined for each of the five sub-regions at NUTS level 3 (Table 15).

Weighting proportions of 55/45 (first expert group) resp. 61/39 (second expert group) lead to similar results and are therefore summarised in one column (Figure 4). Considering the weighting proportions from both expert groups on a differentiated ten class risk matrix (Greiving 2006, in the same volume), two of five sub-regions belong to risk class VI, three sub-regions are awarded risk class III. A significant difference in the risk only occurs, if the share of the vulnerability indicators changes beyond the mark of 50/50. This clearly indicates the stability of the results. However, in the case that changing risk perception would lead to a considerable change in the weighting of vulnerability indicators, a different risk map of the region may result. To illustrate this, fictional weights for the vulnerability indicators are assumed (45/55), representing the transposition of results from the first expert group. Figure 4 shows the results in an ascertained (4a) and fictional (4b) risk map. This underlines Delphi's specific applicability for the consideration of subjective issues of risk perception in more or less homogeneous regions.

Table 14. Aggregated hazard potential in the Dresden region.

Hazard		**Weight**	**Hazarrd intensity in the region***	**Hazard factor**	**Individual hazard score**
Natural Hazards	Volcanic eruptions	**0.2**	1	0.2	**0.0**
	Floods	**24.8**	3	0.6	**14.9**
	Landslides/Avalanches	**2.8**	1	0.2	**0.6**
	Earthquakes	**0.4**	1	0.2	**0.1**
	Droughts**	**9.1**	2	0.4	**3.7**
	Forest Fires	**9.2**	1	0.2	**1.8**
	Storms**	**13.1**	2	0.4	**5.3**
	Extreme precipitation**	**15.0**	2	0.4	**6.0**
	Extreme temperatures**	**4.0**	1	0.2	**0.8**
Technological hazards	Nuclear power plants**	**2.1**	1	0.2	**0.4**
	Production plants**	**5.6**	1	0.2	**1.1**
	Waste deposits**	**4.1**	1	0.2	**0.8**
	Oil spills**	**3.5**	1	0.2	**0.7**
	Dams**	**6.1**	2	0.4	**2.5**
	sum	**100**			**38.6**

* hazard intensities as used in the ESPON Hazards project
** comparative assumption lacking scientific data

Table 15. Derivation of vulnerability classes in the Dresden region (NUTS level III).

NUTS level III Districts (No NUTS V areas)**	**Population density**			**GDP per capita**			**Vulnerability class** Pop. Dens * GDP	
	Value** (pers./km^2)	% (EU 15 average = 100)	class	value*	% (EU 15 average = 100)	class	Results 55/45 and 61/39	Fictional weights 45/55
Dresden Stadt (1)	1.455	1.233	V	23.145	112	III	**IV**	IV
Meißen (17)	242	205	IV	16.149	78	III	**IV**	III
Riesa-Großenhain (23)	149	126	III	14.991	73	II	**III**	II
Sächsische Schweiz (26)	166	141	III	13.025	63	II	**III**	II
Weißeritzkreis (20)	164	139	III	12.012	58	II	**III**	II
EU 15 (100%)***	118	100		20.613	100			

* StLA 2000, except for ***; ** RPS 2004, except for ***; *** CEC 2000

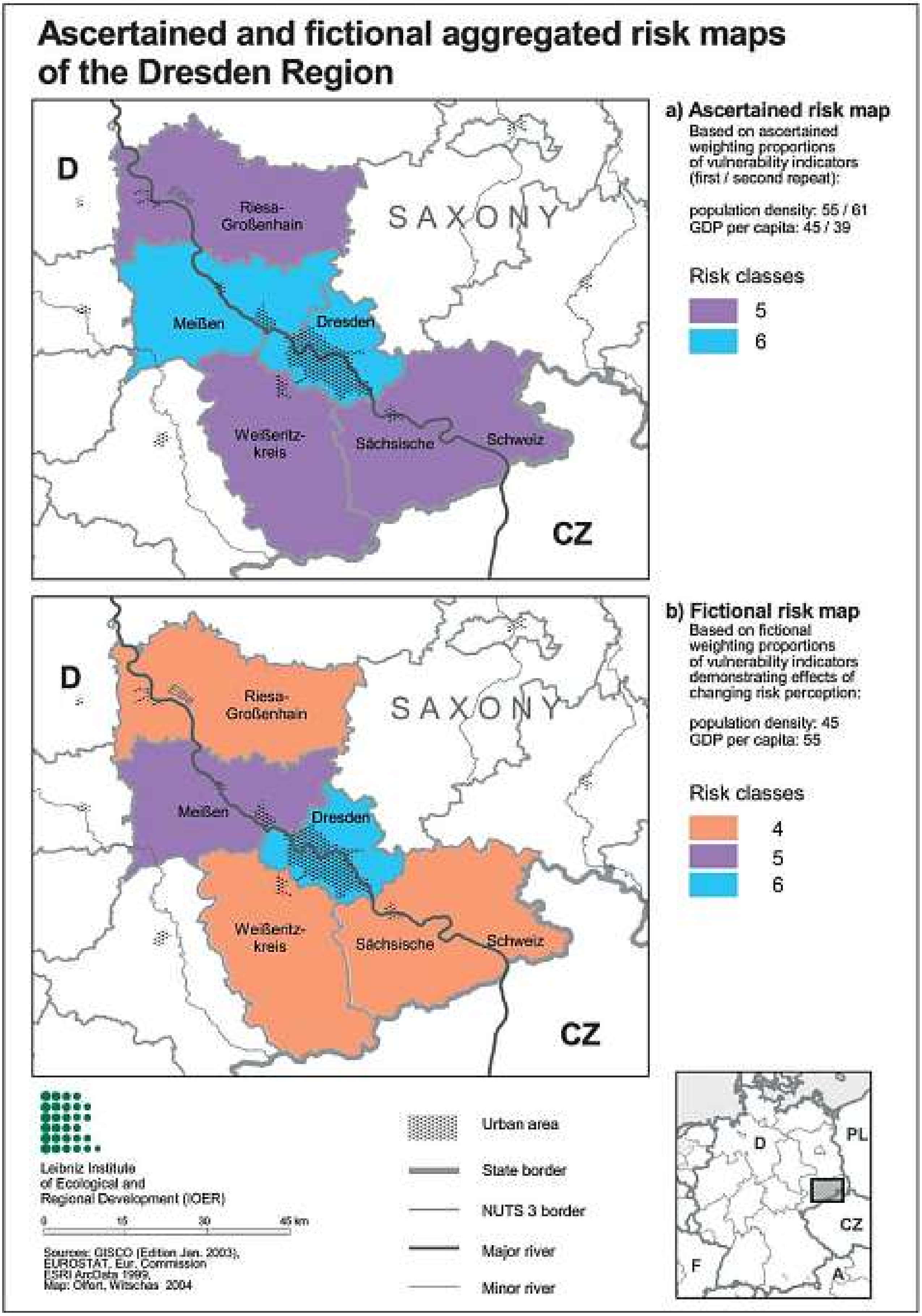

Fig. 4. Ascertained (a) and fictional (b) aggregated risk map of the Dresden region (IOER 2004).

3 THE CENTRE REGION OF PORTUGAL

3.1 Regional Background

The Centre Region of Portugal is one of the five planning and coordination regions in continental Portugal. It occupies an area of 23,668 km^2 (25.7% of the Portuguese land area) and includes 78 districts in 10 sub-regions at NUT III level.

Population: The population is almost 1.8 million inhabitants (17.2% of the national total), of which 65% is made up of population considered active.

Education: An increasing search for the valorisation and training of human resources through the established education system, with a special note for the three universities and six polytechnic institutes, which are spread evenly through the region. Today about 76,000 students attend higher education, of which 89% are public teaching establishments.

Agricultural and forestry: A strong heritage of small cattle and poultry farming and forestry that, despite the profound transformations, continues to play a role in the regional economy. Small farms dominate, are integrated and made viable within a family-based traditional economy.

Industry: The region has stood out due to its diversity, particularly in areas of the manufacturing industry, and moulds the growth that has been both quantitative and qualitative. The sectors with a relatively long tradition in the region are ceramics and glass, products, processes and ornamental rock. The chemical industry and metal mechanics are also important sectors, especially in Baixo Vouga sub-region where the population density is also the highest.

Tourism: Tourism, in its multiplicity of markets segments, is a field of the regional economy with excellent prospects, the qualitative and quantitative emergence of which is already evident, both in the Beira Litoral and in the Beira Interior sub-regions (NUTS III), in terms of supply and demand.

3.2 Natural and technological hazards

Natural hazards

a. Floods

The lower part of the Mondego valley downstream from Coimbra, until the 1980's was almost annually affected by flooding. Flood frequency was lowered with the construction of the Aguieira Dam, which was designed to mitigate flooding up to a 100-year event. In the Mondego River valley, there is a well-marked delimitation of an area, which is normally affected by the century flood and an emergency action plan was devised accordingly by the district civil protection services.

In contrast, the valleys of Vouga e Liz and especially its affluent Águeda River show an uncontrolled flood regime where harmful flooding almost annually occurs. Improper land use in floodplain areas, and forest fires upstream are the main identified reasons for frequent flooding.

b. Forest fires

Most of the Centre Region is classified high and very high risk of forest fire by LD n.º 1056/2004 (August 19th) and LD nº 1060/2004 (August 21). To prevent fire events, especially in the dry season, the Instituto Português de Meteorologia releases on a daily basis the Canadian Index on forest fires vulnerability, from which the national fire brigades draw indicators for their emergency plans for dealing with forest fire hazard. Nowadays it is questionable if forest fires are only a natural hazard or if it is the result of improper land use practices and improvident human behaviour, which makes forest fires much less predictable.

c. Landslides

Landslides could become problematic in case of high rainfall values in areas with severe relief. In the Centre Region, the problem of severe relief in mountainous regions combined with deforestation, usually caused by forest fires and bad planning of construction in the past, is now an important problem and there are no official prevention plans. Emergency plans are implemented by Serviço Nacional de Bombeiros e Protecção Civil (National Firemen and Civil Protection Service).

Technological hazards

a. Water contaminations

Industrialised areas such as the chemical industry and oil refinery in Estarreja city and gas storing in Ovar city, are industries that deal with hazardous substances, and were subject to national legislation published by article 16 of LD nº 164/2001 (Figure 5). Pulp paper mills (Aveiro e Figueira da Foz), manufacturing industries and animal breeding industries in Pinhal Litoral and Dão-Lafões are also hazardous to cause the death to fish in rivers when an accident happens. Measures to prevent or to punish these situations are not yet well implemented but these situations are now subject to enforcement of the law.

b. Radioactivity contamination

The region has no nuclear power plants, but near the border in Spain there is the Almaraz nuclear power station, which could affect the Centre Region in case of an accident. The area could be affected by the spread of radioactivity through the air. Also, the existence of 60 old uranium mine sites where the rupture of waste piles and tailings and radon exhalation can be considered a hazard of great importance with risks to water and dust spread of radionuclides and radon exhalation (Figure 5).

Fig. 5. Hazardous industrial plants (LD nº 164/2001, article 16) and uranium mines in the Centre Region (Schmidt-Thomé 2005 based on INETI 2000).

3.3 Spatial Planning and hazard mitigation

3.3.1 The spatial planning system

The Portuguese planning system is based on the Constitution of 1996, and on law n. 48/98, establishing the guidelines for spatial planning and urban policy. It was regulated through the law – decree n. 380/99, in which the legal system of spatial management planning instruments are drawn at national, regional and municipal levels.

The law – decree n. 555/99, which was altered by the law – decree n. 177/2001, establishes a new legal regime for urban operations at a municipality level (urban plans and detailed plans), a new legal regime for division of urban lands into parcels as well for building activities.

These three integrated (hierarchical) levels of planning aimed at ensuring the different public interests are able to express themselves spatially, in a conciliatory/ agreeable manner, to promote a sustainable economic and social development as well as territorial cohesion.

3.3.2 Instruments of spatial planning

Instruments of spatial management identify human, physical and natural resources, essential for sustainable use/management of the territory as well as setting up basic criteria and minimum levels of usage of those resources to insure that the natural heritage is able to continue renewing itself. Selected instruments are listed in Table 16. Only the municipal spatial plans are able to bind public and private bodies to comply with their rules. All the others solely bind public institutions.

3.3.3 Hazard mitigation in spatial planning practice

The National Council for Emergencies and Civil Protection (CNPCE) is the official board responsible for the coordination of all civil protection services. Within the CNPCE, there are sectoral committees that depend directly upon government even if, in operational terms, they depend on the president of CNPCE. Table 17 represents the levels and instruments of disaster mitigation and the responsible actors in each level.

Table 16. Administrative levels in the Portuguese planning system.

Administrative level	Relevant documentation
National level	*The national policy programme for spatial planning* *Sectorial plans* *Special plans*, inc. protected areas spatial plans, coastlands spatial plans, shallow lakes spatial plans and water protected groundwater plans.
Regional level	*Regional spatial plans* (NUTS level II) *Catchment basin plans* (Mondego, Vouga and Liz rivers) – Coordination and advise to municipalities plans In a sub-regional level, it is able to find the so called *Inter-municipalities plans.*
Municipal level	*Municipal spatial plans* (NUTS level IV) City councils strategic plans (PDMs) Urban plans (PU) Detailed plans (PP)

Table 17. Levels and instruments of disaster mitigation in Centre Region.

Levels / Institution		General Responsible	Disasters / Plan
1st Level - National Council for Emergencies and Civil Protection of Portugal		Portuguese 1st Minister Ministry of the Interior / (Administraçã Interna)	Floods, Forests fires / Water management law Specific laws
2nd Level County Centre for operations of emergency and Civil Protection		Mayor of County Council/ (Governador Civil) Coordenador Regional da Protecçã Civil	Floods, Forests fires Counties
3rd Level – District Centres of Emergences and Civil Protection		Mayor of City (Presidente da Câmara)	Several disasters/ Strategic Document: Municipal Plan for Emergencies and Civil Protection
Instruments and actors of disaster-protection	Disaster prevention	Disaster protection plans (districts, main cities)	Flood-prevention plans (cities, districts) Plans for management and maintenance of flood prevention constructions and flood prediction
	Disaster management	Volunteers, Aid organisations, Units of extended disaster response, Fire-fighters, Technical Aid (THW), in case of requirement: border police, custom, army	Additionally State Environmental Agency, volunteers, private companies

3.4 Exemplary risk review for the Centre Region of Portugal

To extract the importance of potential hazards for the Centre Region, the Delphi Method was applied as a coordination instrument. The goal of the Delphi application in the Centre Region is to depict an exemplary inter-regional risk profile as well as to produce a first aggregated risk map for the region.

As well, refinement was made to the NUTS level IV, adapting choices for NUTS IV level and transformation of results into a regional aggregated risk map for NUTS level IV.

3.4.1 Choice of experts

It was a challenging task to identify a sufficient number of experts with a good overview of the case study area and who are (or have until recently been) working in the area of spatial planning and/or hazards. Finally, ten experts from six different public and private organisations formed the expert group. However, the results were not successful due to the low receptivity of the inquiries by the specialists contacted. In a second phase, the method application was repeated with two different groups of ten experts from six different institutions. The former is made up of researchers and the latter by regional planning authorities, consulting companies and those from the environment and planning ministry. The special relationship of experts to single hazards is avoided.

3.4.2 Choice of hazards and indicators

For the investigation, hazards were chosen to form a representative set of European wide, relevant spatial hazards and accepting that some of those are not represented in the region and consequently would be scored ‘zero’ by the experts. The list of hazards is provided within the result tables below. Vulnerability indicators were refined due to the availability of additional and finer resolved data.

3.4.3 Application of the Delphi Method

The Delphi inquiry was to be applied with one expert group only. Later in the process, further inquiries were made to ensure highest possible representativeness of results. As a result, two expert groups were involved. In both expert groups, the inquiry was conducted over three rounds. Prior to the inquiry, the experts were informed of the background of the test and the attitude of the method used was emphasised. All experts were contacted personally or by post. Experts were instructed to consider feedback information provided after the first and second repeats.

3.4.4 Weighting the hazards

Both groups provided interesting remarks regarding floods, forest fires and landslides. Researchers (first group) tended to give less weighting to floods and forest fires while in the third round the tendency was to raise the weighting of these two hazards. The first group also gave more importance to landslides than the second group (planners and regional authorities). The reason may be the frequency (more emphasised in case of forest fires) and economic impact that forest fires and floods tend to have every year. Researchers tend to observe the probabilities of occurrence under certain circumstances more and not the event itself. However, it became apparent that the most importance was attached to natural hazards (first/second groups 77/80%), with forest fires (26/37%), floods (20/21%) and landslides (10/8%). Technological hazards in total received only 23/19% with major accident hazards in chemical plants in first (11/9%). In case of technological hazards, the results diverged between both groups (see Table 18).

Between Round 1 to Round 3 the largest relative change experienced were the estimations for droughts, earthquakes and storm surges with the smallest for volcanic eruptions, snow avalanches and hazards from nuclear power plants. At the same time, these hazards, however, are the four lowest estimated hazards although the changes estimated in case of droughts should be observed carefully and may be related to the drought definition between both groups.

The coordination process induced by the use of the Delphi method was more effective for the second group where all hazard results seems to converge, which was not the case in the first group where snow avalanches, droughts, forest fires and air traffic diverged from the first to the third repeat.

By observing the results of the two groups of Delphi inquiry in this stage, it is evident that both groups reach different results. However, it is possible to see that the second group of regional authorities, decision makers and consulting company people are more coherent between them and respect the efficiency of the rules of Delphi method more. There-

Table 18. Weighting of hazards, average estimations and their change in expert groups.

Hazards		Average estimation Expert group 1			Average estimation Expert group 2			Change in estimation Round 3/ Round 1 (%) Expert group 1	Change in estimation Round 3/ Round 1 (%) Expert group 2
		Round 1	**Round 2**	**Round 3**	**Round 1**	**Round 2**	**Round 3**		
Natural Hazards	Volcanic eruptions	0.0	0.0	**0.0**	0.0	0.0	**0.0**	100	100
	Large River Floods and Flash Floods	19.0	19.3	**20.9**	21.0	21.2	**20.4**	110.0	97.3
	Storm Surges	5.4	4.0	**4.1**	3.2	3.8	**3.7**	75.2	115.6
	Snow Avalanches	0.6	0.1	**0.1**	0.0	0.1	**0.0**	100.0	100.0
	Tsunamis	0.6	1.2	**0.9**	0.8	0.9	**1.1**	156.7	140.0
	Landslides	10.4	10.2	**9.4**	7.6	8.0	**8.4**	90.4	110.0
	Earthquakes	2.6	4.3	**3.6**	3.2	3.0	**3.0**	137.7	92.5
	Droughts	7.8	4.7	**4.1**	1.0	1.8	**2.3**	52.3	234.0
	Forest Fires	24.0	27.0	**28.4**	38.2	36.1	**35.4**	118.4	92.6
	Winter Storms	4.0	3.0	**2.3**	2.2	1.8	**2.0**	58.5	90.9
	Extreme temperatures	3.0	3.3	**3.2**	3.6	3.7	**4.3**	105.3	118.9
Technological hazards	Hazards from Nuclear Power Plants	3.6	2.9	**3.1**	3.7	3.5	**3.4**	87.2	93.0
	Major accident hazards	10.2	11.0	**11.4**	9.6	9.6	**9.1**	111.8	94.8
	Hazards from oil production. processing. storage and transportation. including major oil spills	7.4	7.4	**7.4**	4.6	5.2	**5.5**	100.0	119.6
	Air traffic hazards	1.4	1.5	**1.1**	1.3	1.4	**1.2**	77.1	92.3
	sum	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**99.8**		

fore, for further analysis, only the results of the second expert group were used.

3.4.5 Risk profile of the Centre Region of Portugal

By applying the ESPON Hazards approach, an aggregated hazard score for the Centre Region of Portugal was obtained that amounted to 51.7% of a potential maximum of 100%. This corresponds with aggregated hazard class III. Considering weighting factors of vulnerability indicators, the final vulnerability class was determined for each of the ten subregions at NUTS level III (see Table 19 and Table 20).

At NUTS level III, vulnerability is applied with the same weighting used by the ESPON Hazards project for the generation of European-wide maps. Vulnerability indicators are weighted using the Delphi Method. The indicators used for damage potential were population density and regional GDP per capita, and for coping capacity national GDP per capita was used (Table 19 and Table 20):

Vulnerability = Damage potential (25%+25%)
– Coping capacity (50%)

Considering general vulnerabilities as coping capacity and damage potential and using the same methodologies used in European maps, with the exception of fragmented natural areas not used in this case, the results show that NUTS III regions near the coastline with high development have higher risk.

In contrast to other case study areas, in the Centre Region data availability allows for the refinement of weighting results to NUTS level IV. For this reason, an alternative set of vulnerability indicators has been used:

Damage potential: Regional GDP referred to national data; Population density referred to national data; Population Lost referred to national data.

Coping capacity: Doctors/1000 inhabitants; number of firemen/area.

All vulnerability indicators were weighted 20% but coping capacity was calculated considering the lowest number of doctors per 1000 inhabitants as

Table 19. Damage potential indicators of NUTS level III in the Centre Region of Portugal.

Districts (NUTS 3)	**population density** (25%)			**GDP per capita** (25%)			
	value 1999 (pers./km^2)	**%** with EU 15 average = 100%	**class**	**value 2000**(€)	**%** with EU 15 average = 100%	**class**	**calculated vulnerability class**
Beira Interior Norte	27	23	II	7.311	35	I	**I**
Pinhal Litoral	131	111	III	10.104	49	I	**I**
Pinhal Interior Sul	13	11	I	7.680	37	I	**I**
Beira Interior Sul	20	17	I	8.618	42	I	**I**
Cova da Beira	64	54	II	7.321	36	I	**I**
Serra da Estrela	56	47	II	5.998	29	I	**I**
D„o Lafıes	142	120	II	7.246	35	I	**I**
Pinhal Interior Norte	50	42	II	6.578	32	I	**I**
Baixo Mondego	154	131	II	10.198	49	I	**I**
Baixo Vouga	196	166	II	10.568	51	II	**I**
reference (EU 15=100)	**118**	**100**		**0.613**	**2100**		

Table 20. Coping capacity indicator of NUTS level III in the Centre Region of Portugal.

Districts (NUTS 3)	**National GDP per capita*** (50%)				
	value 2003(€)	% with EU 15 average = 100%	**class**	**vulnerability class**	**DP+CC/2**
Beira Interior Norte	12.500	56	IV	**II**	**I**
Pinhal Litoral	12.500	56	IV	**II**	**II**
Pinhal Interior Sul	12.500	56	IV	**II**	**I**
Beira Interior Sul	12.500	56	IV	**II**	**I**
Cova da Beira	12.500	56	IV	**II**	**I**
Serra da Estrela	12.500	56	IV	**II**	**I**
D„o Lafıes	12.500	56	IV	**II**	**II**
Pinhal Interior Norte	12.500	56	IV	**II**	**I**
Baixo Mondego	12.500	56	IV	**II**	**II**
Baixo Vouga	12.500	56	IV	**II**	**II**
reference (EU 15 =100)	**22.432**	**100**			

* CCDRD 2001; DP-damage potential; CC-coping capacity

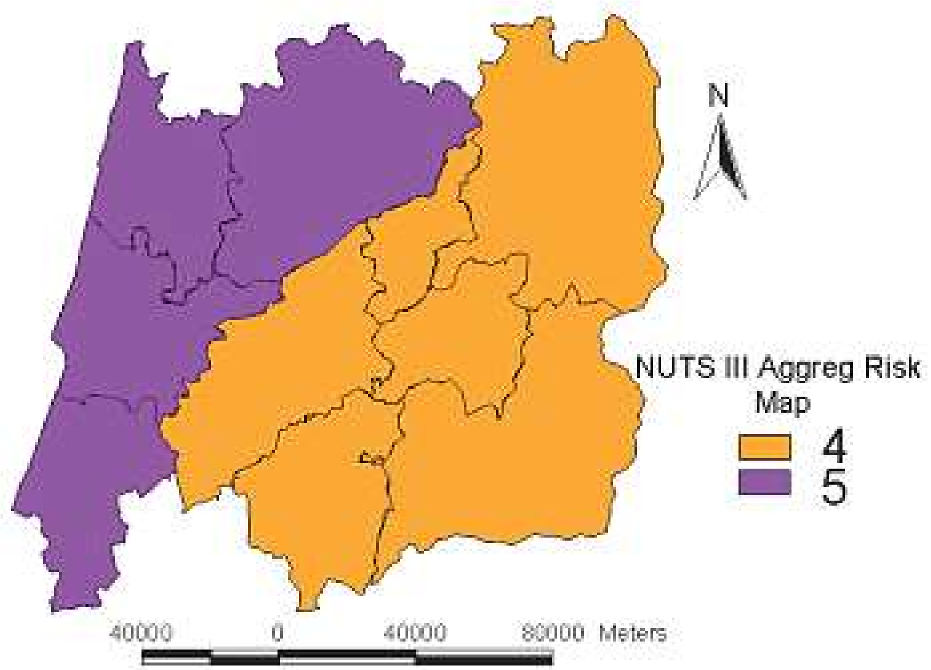

Fig. 6. Aggregated risk map of the Centre Region of Portugal for NUTS level III (Schmidt-Thomé 2005).

5 (the high vulnerability areas) and 1 the higher number of doctors per 1000 inhabitants as the low vulnerability areas. The same methodology was used for the number of fireman / areas.

These maps are based in ESPON Hazards methodology but may not reflect the real regional vulnerabilities. However, the damage potential and coping capacity indicators chosen were to be applied in all hazards of the study. In the future, more tests and new approaches should be tried (Figure 7).

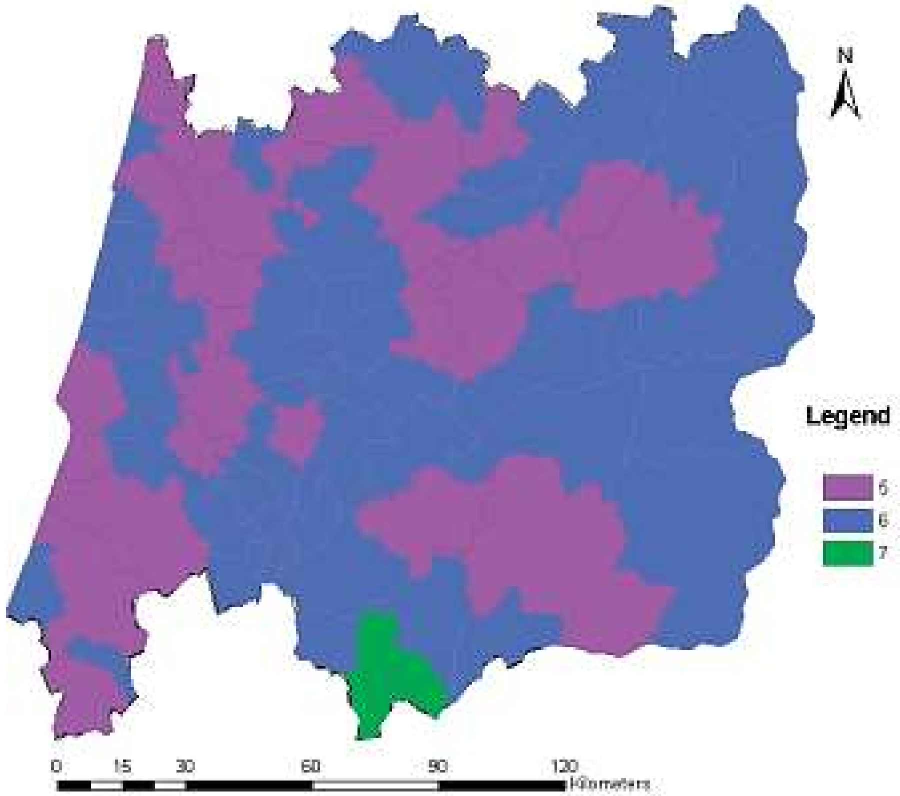

Fig. 7. Aggregated risk map of the Centre Region of Portugal for NUTS level IV (Schmidt-Thomé 2005).

4 CONCLUSIONS FROM CASE STUDIES

4.1 Conclusions regarding the application of the Delphi method

Applied to the weighting of hazards, the Delphi method offers indicative and subjective information. However, given that the question of weight is uncertain and partially subjective, the chosen approach to weighting appears to be useful. Critical for the quality of results is the careful selection of participants for the expert panel. The quality of results not only relies on the expert's knowledge of the issue, but also on the acquaintance with concepts used (e.g. risk concept) and the preparedness to fully accept the inquiry method. The clearness of the matter of weighting is decisive in relation to the comparativeness of replies. For example, certain hazards may be perceived as overlapping if not precisely defined and delimited against each other.

With respect to weighting, potential sources of distortion must be considered. One of those is the possible overestimation due to the presence of recent events. This seemed to be the case in the Dresden region where the first inquiry was done a few months after the August 2002 flood. Another source is underestimation due to unawareness of risk, like in the case of infrequent events. Also, missing knowledge of hazard propagation can lead to distortion in either direction. Furthermore, current events can considerably change results as remarkably proved in the case of the December 2004 tsunami that occurred during the European wide application of the method (Schmidt-Thomé 2005, chapter 3).

Appealing to subjective risk perception, the method assumes culturally homogenous areas. As a result, its applicability is limited to areas that indeed show a high cultural homogeneity, as can be expected in NUTS level II, III or even smaller.

1.4.3 Conclusions regarding the method for inner-regional risk review

The consensus based regional risk profile is useful as information for the regional planning practice. The consideration of relative weights of hazards is a valuable contribution to transparency in decision-making in spatial planning and could lead to better acceptance of measures and instruments for risk reduction (term see Olfert & Schanze 2005). As a result, the prevailing selective consideration of single hazards is put into perspective.

Regional risk profiles offer a fast and simple manner to accomplish an overview of the distribution of aggregated risk within the region. Results for each reference area of the region represent indicative information. The statement is generalised for the whole reference area and does not reflect the internal minima and maxima. Therefore, risk profiles are especially expressive, where risk aggregation can be accomplished for several sub-regions. The refinement in the Centre Region clearly shows that a sub-region of medium risk can be made up of areas with very low risk and some with very high risk.

In general, the obtained results are indicative and the level of detail is defined by data availability. The target users of this application are super-ordinate stakeholders for whom the profiles can be a basis for prioritisation or risk management activities. However, regional risk-profiles cannot aim at replacing the missing detailed risk assessment using more elaborate methods, such as the case specific modelling of hazards and vulnerability or the purposeful inquiry of required data.

The biggest challenge remains the provision of sufficiently resolved hazards data incl. hazard-specific exposure and vulnerability. The representativeness of applied information remains limited for uncertain hazard data. This especially applies with rising natural and societal heterogeneity of the reference area. Particularly, vulnerability methodology and indicators need further advancement to allow for comprehensive and representative consideration of multiple risks. The chosen reference level (NUTS III) used as a basis for the investigation offers only limited information needed for local level of spatial planning. However, the Ruhr District case offers some ideas for a more detailed regional risk assessment based on the analysis of given hazard intensities, including thematic information that leads to more detailed results.

Nevertheless, the applied procedure for deriving inner-regional risk profiles offers valuable indicative information for super-ordinate administrative levels even though there is a lot of potential for further development, especially in relation to the availability of impartial data. However, lacking the applicable tools of multi-risk assessment, the inner-regional risk profiles offer the first basic information that may allow regional planning stakeholders to approach systematic multi-risk response.

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RECOMMENDATIONS FOR A RISK MITIGATION ORIENTED EUROPEAN SPATIAL POLICY

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Peltonen, L. 2006. Recommendations for a risk mitigation oriented European spatial policy. Natural and technological hazards and risks affecting the spatial development of European regions. *Geological Survey of Finland, Special Paper 42,* 153–167, 1 table.

The inclusion of hazard awareness in EU policies is discussed to determine how natural and technological hazards are addressed in EU regulation and policies. First, the different policy options and their political underpinnings are discussed at the general level. Second, a set of key EU policies are reviewed for the status of hazards and risk awareness in these policy sectors. The EU level and the meso-level of interregional co-operation will be discussed with regard to spatial scales. It is argued that no uniform and holistic approach within the EU exists to deal with natural and technological hazards. Overall, a better inclusion of risks related to technological and especially natural hazards in EU policies is needed. Nevertheless, risks are becoming increasingly important on the EU agenda. The implementation of recent legislation and the success of envisaged cohesion policies for the upcoming 2007–2013 term are crucial in this respect. To conclude, a set of recommendations arising from the review are summed up. The article is based on research carried out in the ESPON 1.3.1 Project on natural and technological hazards.

Key words: natural hazards, technological hazards, European Union risk management, preventive measures, Europe

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1 INTRODUCTION

Natural and technological hazards pose challenges for balanced and sustainable development in Europe. Citizens, cities and regions are exposed to hazards in varying degrees, placing them in different "risk positions". Consequently, the role of hazards and risk mitigation can be seen as a specific element of sustainable development, as it constitutes an important task for the EU cohesion policy. The EU Policy instruments can contribute to even out these differences as a matter of European solidarity. There are several elements in EU legislation, policies and programmes pointing to the need for including hazards and risk management into planning and decision-making as mainstream concerns. They have become increasingly visible in EU policies and legislation, along with to the recent integration of environmental concerns and sustainable development. The inclusion of hazard awareness in EU policies is discussed to determine how natural and technological hazards are addressed in EU regulation and policies. The article is based on research carried out in the ESPON 1.3.1 Project on natural and technological hazards (Schmidt-Thomé 2005). First, the different policy options and their political underpinnings are discussed at the general level. Second, a set of key EU policies are reviewed for the status of hazards and risk awareness in these policy sectors. The focus is on EU Regional policy and Environmental policy – along with the integration between the two. The EU level and the meso-level of interregional cooperation will be discussed. The review of EU policies and initiatives is then discussed. Overall, a better inclusion of risks related to technological and especially natural hazards in EU policies is needed. It should be noted, however, that risks are becoming increasingly important on the EU agenda. The success of envisaged policies for the upcoming 2007–2013 term is crucial in this respect. To conclude, a set of recommendations arising from the review are given.

2 POLICY ORIENTATION: FOCUS ON PREVENTIVE ACTION AND INTEGRATION

The notion of risk can be understood as a progression with different structural and situational elements leading to disaster situations (e.g. Blaikie et. al. 1994). One way to formulate this idea is the DPSIR indicator chain[1] used by the European Environmental Agency, which distinguishes between different elements in the chain of hazard progression or, more generally, unwanted environmental change. These elements include *driving forces*, that is, broader structural variables behind certain changes, *pressures*, referring to more immediate forces, indicators of the *state* of the environment, *impacts* of the event/change and the elicited *responses* from human and social actors. Different policy options may be crafted according to which element in the hazard progression chain is targeted. Far-reaching and holistic policy measures should address the root causes of hazards, not merely reacting to disaster events. An important aspect in tackling the challenge posed by hazards is to shift from a reactive (post-event) disaster-orientation to a *preventive orientation* that concentrates on risk management and mitigation. Civil protection and disaster (ex-post) response, for instance, are important factors in the way individuals, families, localities and regions cope with natural and technological hazards and disaster events. Civil Protection, however, is only part of coping with hazards. Cooperation should be strengthened especially in the field of risk mitigation through planning.[2] In the scope of the ESPON Hazards project, spatial planning was seen as an important preventive instrument for mitigating risks. Thus, the project focused on spatial analysis and the development of spatial planning measures, instead of discussing previous post response measures.

[1] The indicator categories behind the abbreviation are: Drivers, Pressures, State, Impact and Responses.

[2] The new EU constitution seeks to encourage cooperation between Member States in the field of civil protection to improve the effectiveness of systems for preventing and protecting against natural or man-made disasters within the Union. In response to the events of September 11th, the EU civil protection activities have focused on the rapid implementation of the Community Mechanism for Civil Protection. The scope of the EU intervention in this field encompasses actions to reduce the consequences of Chemical, Biological, Radiological and Nuclear (CBRN) threats to society. The ESPON 1.3.1 project has focused, instead of civil protection, on prevention through spatial planning instruments.

In accordance with the preventive orientation, risk management strategies and policies should, instead of focusing on the disaster events, aim at a broader strategy of *vulnerability reduction, that is* not putting people and/or other valuable assets in harm's way. Blaikie (1994, 9) defines vulnerability as *"the characteristics of a person or group in terms of their capacity to anticipate, cope with, resist and recover from the impact of a natural hazard."* Vulnerability reduction should balance the efforts taken towards post-event disaster response, rescue and recovery. From this perspective, spatial and urban planning should be seen as key instruments (cf. UNISDR 2002: 224).

This orientation is based on the evidence that disasters are more the result of human and societal activities shaping spatial patterns of damage potentials and coping capacities rather than the changes in the frequencies and magnitudes of the extreme hazard events themselves. 'Human-made' societal and spatial developments alter the patterns of vulnerability far more forcefully than 'natural' driving forces such as climate change. (Sarewitz et al. 2003) While stressing the importance of changes in 'human-made' vulnerability patterns related to European river floods, Mitchell (2003, 573) notes that "there is ample reason to be concerned about the growth of flood disaster potential […] even without taking climate change into account." In addition, the uncertainties involved in understanding the complex dynamics of climate change favour the strategy of vulnerability reduction. In fact, climate change seems to have acquired attention from the policy and research communities, which is probably larger than its significance as a driving force affecting risk patterns across Europe.

It is important to note that public policies mitigating the impacts of extreme events differ depending on whether they focus on reducing risk or reducing vulnerability. While risk-based approaches to preparing for extreme events focus on acquiring accurate probabilistic information about the events themselves, reducing vulnerability does not demand accurate predictions of the incidence of extreme events. While defending the vulnerability reduction strategy, Sarewitz et al. (2003) point out that extreme events are created by context and that vulnerability reduction is a human rights issue while risk reduction is not. Addressing vulnerability means addressing the distribution of the impacts of the hazard among a population. It should therefore be recognized that risk mitigation is not only a technical endeavour, but also involves political issues with normative underpinnings.

3 TOWARDS TERRITORIAL COHESION

Thus far, there is no uniform or holistic approach within the EU to deal with natural and technological hazards. Hazards are addressed in heterogeneous and partial ways, and at different levels by existing Community instruments. It is clear that policy responses to technological hazards are much better developed, mainly through the Seveso II Directive, than those addressing natural hazards. (such as the European Environment Agency 2003, 62–63.) While the Seveso II Directive provides a legislative basis for the mitigation of hazards resulting from major accidents[3], no such basis for reducing natural hazards exists in the EU. This discrepancy is all the more severe when contrasted against the current trends in natural and technological hazards. First, the trend in the annual number of natural hazard events is more obviously upward than for industrial accidents. Second, the losses related to natural hazards demonstrate an even stronger trend. For instance, the economic losses due to floods and landslides in Europe over the seven-year period from 1990–1996 were four times as large as the losses in the previous decade, between 1980–1989. (European Environment Agency 1999, 231–232.) Thus, it is clear that the focus in European policy should be on developing adequate mitigation measures towards risks arising from natural hazards.

Several initiatives in the EU have stressed the importance of including hazards and risk management into decision-making as mainstream concerns. The number of initiatives is, of course, not directly indicative of their relative weight in decision-making. For instance, the European Spatial Development Perspective (ESDP) (European Communities 1999), goal 142 underlines the importance of spatial planning in protecting humans and resources against nat-

[3] See http://europa.eu.int/comm/environment/seveso/.

ural disasters.[4] This goal is linked to policy option 46, which includes the "Development of strategies at regional and transnational levels for risk management in disaster prone areas." Moreover, as part of the so-called "post-ESDP" process, the EU Working Group on Spatial and Urban Development clearly proclaimed as part of their key messages, that *"areas at risk from large-scale natural disasters (e.g. flooding) need risk assessment and management incorporating a European perspective."* (SUD 2003, 2). However, the unofficial and non-compulsory character of the ESDP means that it cannot directly affect spatial development or significantly influence EU policy (e.g. Atkinson 2001, 399). The lack of EU-level authority in spatial planning makes it all the more important to ensure that the sectoral policies of the union support risk reduction in a complementary fashion.

The recent introduction of the notion of territorial cohesion is important in this respect. Territorial cohesion refers to the balanced distribution of human activities across the European Union. As such, it complements the notions of economic and social cohesion. It covers the territorial dimension of social and economic cohesion and is closely linked to the fundamental EU objective of "balanced and sustainable development" (Art. 2 EU-treaty). The notion also demands a more integrated approach, from a territorial perspective, to both EU investments directly relevant to the cohesion of the European territory (structural funds/cohesion fund) and other relevant EU policies. The territorial cohesion objectives provide new openings for risk mitigation to move towards the centre of EU policy priorities. Thus far, clauses concerning civil protection and sustainable development have both been included in the EU treaty. This has not meant, however, that risk mitigation is also included in the treaty in an explicit way, even if it is related to both environmental and civil protection.

At present, the civil protection approach should be broadened towards preventive measures while the goal of sustainability should be broadened to recognize natural hazards as a threat to livelihoods and the environment. Although disaster resilient communities are not identified as a specific objective of Article III-129 ("Environment"), disaster resiliency will be an important prerequisite for reaching the named objectives of "preserving, protecting and improving the quality of the environment" and "protecting human health". Moreover, Section 5 ("Civil Protection"), Article III-184 determines that *"the Union shall encourage cooperation between Member States in order to improve the effectiveness of systems for preventing and protecting against natural or man-made disasters within the Union. Union action shall aim to: (a) support and complement Member States' action at national, regional and local level in risk prevention, in preparing their civil-protection personnel and in responding to natural or man-made disasters"*. Here it is evident that the focus on civil protection is disaster-oriented and the responsibilities of the EU are seen as complementing Member States' action.

In sum, risk management should be seen more explicitly as an important tool for achieving the goals of human development inside the EU. The inclusion of a risk management perspective in EU policy requires three dimensions of integration: horizontal integration of policies and financial instruments, vertical integration of spatial planning scales from the local to the EU level and horizontal integration of different aspects of resilience towards hazards at the local and regional planning level. A necessary task at the local and regional levels is to integrate different hazards into one management scheme, taking into account their interrelated nature. Here, the recently adopted Strategic Environmental Assessment (SEA) directive is of key importance.

[4] Goal 142 of the ESDP states that "[…] spatial planning at suitable government and administrative levels can play a decisive role [...] in the protection of humans and resources against natural disasters. In decisions concerning territorial development, potential risks – such as floods; fires; earthquakes; landslides; erosion; mudflows; and avalanches and the expansion of arid zones should be considered. In dealing with risks, it is important, in particular, to take the regional and transnational dimensions into account."

4 STRUCTURAL FUNDS IN RELATION TO RISKS AND HAZARDS

The primary aim of the EU structural funds is to reduce the socio-economic disparities that exist between different regions. Such disparities hinder the cohesion of the EU, which is one of EU's primary objectives. It should be acknowledged that natural and technological hazards influence European cohesion in a negative way by impeding the development of regions burdened by disaster events and resulting losses. Thus, it is important that hazards be taken into account when financing operations through Structural Funds. At present, the general provisions on the Structural Funds do not mention natural or technological hazards, nor have they been mentioned in the official regulations on the four Structural Funds for the period of 2000–2006.

In July 2004, however, the European Commission adopted its legislative proposals for cohesion policy reform covering the period of 2007–2013 (COM(2004) 492–496). Environmental protection and risk prevention have been given much more emphasis than before. The Commission proposes a set of key themes for the regional programs that are especially important for the cohesion of the EU. Risk prevention is mentioned as a priority under all the three objectives of convergence, regional competitiveness and employment and European territorial cooperation.

The first priority, convergence, acknowledges the need to help the least developed Member States and regions, for example by supporting plans aimed at preventing natural and technological risks. The second priority of regional competitiveness acknowledges natural hazards under "Infrastructure for a high-quality environment". Here, preventive measures in natural areas exposed to disasters are considered important for attaining a high-quality environment. The third priority, territorial co-operation, acknowledges risk prevention at cross-border, transnational and interregional level. Territorial cooperation objectives include the following themes: maritime security, protection against flooding, protection against erosion, earthquakes and avalanches. These themes are to be addressed through actions such as supply of equipment, development of infrastructures, transnational assistance plans and risk mapping systems.

In the field of rural development, the Commission adopted a proposal (COM (2004) 490) on support for rural development by the European Agricultural Fund for Rural Development (EAFRD), which will replace the current regulation for the next programming period of 2007–2013. Within the EAFRD, risks are addressed in relation to natural resource management, for example, through development of forest resources and their quality and the prevention of forest fires affecting agricultural and forestry production. Also, the fisheries policy for 2007–2013 allows for the reconstitution of the production potential of the fisheries sector damaged by natural or industrial disasters.

In the summary of the guidelines, it is stressed that in areas prone to danger from natural disasters preventive civil protection measures should be encouraged. Further, Structural Fund assistance must give priority to investments that follow a preventive approach to environmental hazards. The Commission indicative indicative guidelines under these objectives should help member states draft their programming documents in ways that address vulnerability reduction and risk mitigation. The fact that these guidelines exist and acknowledge hazards doesn't automatically mean that operations concerning them exist. However, the guidelines have to be taken into account when Member States prepare regional development plans and programming documents for the three priority objectives, to get assistance under the Structural Funds and the Cohesion Fund.

In the Structural Funds regulations, environmental issues and sustainable development are taken into account in ERDF, EAGGF and FIFG.[5] Environmental concerns and sustainable development can be linked to hazards in many cases, for example in the protection of marine resources in coastal waters (FIFG), oil spills need to be considered as one threat to marine resources. In addition, the indicative guidelines for receiving funding from the Structural Funds state that the Structural Funds and the Cohesion Fund should assist compliance with the environmental standards established in the relevant Community Directives.

It is of great importance that natural and technological hazards are taken into account in the first priority, which comprises most of the new Member

[5] The abbreviations stand for different instruments of EU regional policy, i.e. European Reconstruction and Development Fund, European Agricultural Guidance and Guarantee Fund, Financial Instrument for Fisheries Guidance.

States of the EU.[6] The new member states are generally more vulnerable to hazards due to their economic status. Economic growth in these countries is bound to be fast in the years following the accession, and in such a situation, the existence of hazards must be considered carefully.

By looking at the remodeling of the cohesion policy for the 2007–2013 period, it seems that taking natural and technological hazards into account in regional development is becoming an increasingly important criterion for receiving financing through the Structural Funds. It should be ensured that Structural financial instruments make a contribution to taking the prevention of natural, technological and environmental hazards into account in regional development. It is crucial that the emphasis of actions lies on the prevention of risks, not only on helping in the aftermath of disasters.

In the scope of post-disaster recovery and relief, instigated by the large number of recent disastrous natural hazards such as the dramatic floods, the Commission set up the Community Solidarity Fund (EUSF) in 2002 to help regions recover.[7] The EUSF will "intervene mainly in cases of major natural disasters with serious repercussions on living conditions, the natural environment or the economy in one or more regions of a Member State or a country applying for accession." (http://europa.eu.int/scadplus/leg/en/lvb/g24217.htm) Ecological disasters from oil spills are fought with the help of the European agency for maritime safety, as well as with a possible compensation fund for damage from oil spills. Despite these efforts, the impact of recent disasters on the economy of the affected regions exceeds the capacity of existing compensation mechanisms. This underlines the importance of prevention.

5 RECENT EU INITIATIVES

Several measures in the field of European environmental policy have an influence on land use and vulnerability, notably the Directives on Environmental Impact Assessment (EIA) and Strategic Environmental Assessment (SEA), as well as the Water Framework Directive (WFD). Article 12 of the Directive on the control of major accident hazards ("Seveso II") requires that Member State's land-use planning and/or other relevant policies take into account the objectives of preventing major accidents and limiting the consequences of such accidents. The inclusion of natural hazards is less developed in the field of environmental policy, evidently because nature has not been seen as a potential threat to the 'environment'. Furthermore, public participation in environmental decision-making is an important element in these procedures, in line with the Aarhus Convention.

The Sixth Environment Action Programme (EAP)[8] indicates that the EU needs a coherent and consolidated policy to deal with natural disasters and accidental risk. As key concerns, the 6th EAP seeks to 1) promote Community coordination to actions by Member States in relation to accidents and natural disasters by, for example, setting up a network for exchange of prevention practices and tools; 2) develop further measures to help prevent the major accident hazards with special regards to those arising

[6] At present, the aim of objective 1 of the Structural Funds is to promote the development and structural adjustment of regions whose development is lagging behind. Objective 1 is "regionalised", meaning that it applies to designated NUTS level II areas in the *Nomenclature of Territorial Units for Statistics* developed by Eurostat. Of these geographical areas, only those with a per capita gross domestic product (GDP) lower than 75% of the Community average are eligible. See http://europa.eu.int/scadplus/leg/en/lvb/g24203.htm.

[7] According to the EUSF provisions, a natural disaster is considered as 'major' if, within a single country, the damage caused exceeds over EUR 3 billion (2002 prices), or more than 0,6% of gross national income. Or, in case of extraordinary regional disaster, if damage is less serious but causes serious and lasting repercussions on living conditions and the economic stability of the region. Particular attention is paid to remote and isolated regions. Eligible costs include: 1) Immediate restoration of infrastructure; 2) Providing temporary accommodation and funding rescue services to meet the immediate needs of the population concerned; 3) Immediate securing of preventive infrastructures and measures of immediate protection of the cultural heritage, and 4) Immediate cleaning up of disaster-stricken areas. (http://europa.eu.int/scadplus/leg/en/lvb/g24217.htm)

[8] Environment 2010: Our future, Our Choice – The Sixth Environment Action Programme – COM (2001) 31 final. http://europa.eu.int/eur-lex/pri/en/oj/dat/2002/l_242/l_24220020910en00010015.pdf

from pipelines, mining, marine transport of hazardous substances and developing measures on mining waste.

Regarding natural hazards, climate change is seen as an important driving force, which is specifically mentioned in Article 5 of the 6EAP: "In addition to the mitigation of climate change, the Community should prepare for measures aimed at adaptation to the consequences of climate change, by 1) reviewing Community policies, in particular those relevant to climate change, so that adaptation is addressed adequately in investment decisions; 2) encouraging regional climate modeling and assessments both to prepare regional adaptation measures such as water resources management, conservation of biodiversity, desertification and flooding prevention and to support awareness rising among citizens and business". *As it seems that climate change adaptation is becoming a pervasive trend in environmental policy, it should be guaranteed that focusing on this driving force does not exclude measures related to other driving forces influencing socio-economic vulnerability patterns in Europe.*

As to technological hazards, the 6EAP suggests measures to help prevent industrial accidents. The Seveso II Directive is seen as a good basis for managing industrial risks but it proposes that the scope of the Directive should be extended to cover new activities such as mining accidents and pipelines (p. 32). In addition to the human and health impacts of disasters, the 6EAP also points out that disasters are also a threat to natural areas and wildlife. This points to the need for further development of indicators for ecological vulnerability in relation to both natural and technological hazards.

The 6EAP stresses the importance of community coordination to Member States' action on accidents and natural disasters. Such coordination efforts have been promoted through the Commission Work Programme for 2002, which foresees the development of an integrated EU strategy on prevention, preparedness and response to natural, man-made and other risks.[9] The intention to adopt such a strategy was confirmed in the recent Communication on "*The EC response to the flooding in Austria, Germany and several applicant countries*" (COM(2002)481).[10]

Another ongoing development is related to monitoring. The Commission is preparing a proposal for a framework Directive to create a policy and legal framework for the establishment and operation of an Infrastructure for Spatial Information in Europe (INSPIRE). It will make harmonized and high-quality spatial (geographic) information readily available for formulating, implementing, monitoring and evaluating Community policies and for providing information to the citizen in a wide range of sectors at local, regional, national or international level. The development of the spatial information infrastructure will have a major effect in improving the range and quality of spatial data available to those involved in urban design and land-use planning. It also facilitates environmental impact assessment efforts (Vanderhaegen and Muro, 2005).

Descending from the EU-level to the regional and local actors, the recent thematic strategy on the urban environment[11] is of high interest for the 1.3.1 project, since urban areas are characterized by high damage potentials in the face of disasters. The thematic strategy carries many important initiatives that can be linked to risk reduction efforts. These include proposed actions such as comprehensive urban environmental management plans (p. 12) and encouraging member states to "evaluate the consequences of climate change for their cities so that inappropriate developments are not begun and adaptations to the new climatic conditions can be incorporated into the land use planning process" (p. 31) However, a comprehensive risk management perspective is still lacking in the strategy.

Another interesting development from the regional perspective is the Water Framework Directive

[9] Commission workplan 2002: COM (2001) 620 final. http://europa.eu.int/eur-lex/en/com/cnc/2001/com2001_0620en01.pdf

[10] The strategy includes the following points: i) Initiative for developing action plans to reduce the level of risks in the most vulnerable areas; ii) Integration of the risk component in all Community policies, in the same way as the "environmental component" is taken into account. (For example, no support to projects that would increase the risk to people, request to carry out a Risk or Vulnerability Assessment of a project in the same way that an Environmental Impact Assessment is requested); iii) Access to best practices based on the experience gained during recent emergencies; iv) To promote, as possible and necessary, further preventive measures within the Structural Fund. http://europa.eu.int/comm/environment/civil/pdfdocs/integrated_strategy_meeting021112.pdf

[11] COM(2004)60 final. http://europa.eu.int/eur-lex/en/com/cnc/2004/com2004_0060en01.pdf

(WFD) (2000/60/EC).[12] The WFD goal to establish a framework for the protection of inland surface waters, transitional waters, coastal waters and groundwater to protect ecosystems, reduce pollution and promote sustainable water use. The relevance for hazards arises from two reasons; first, the purpose of the directive is to *contribute to mitigating the effects of floods and droughts*. (Article 1, L 327/5) and, second, from the fact that the directive introduces an interesting management tool in assigning *river basin districts* as prime unit for the management of river basins (Article 3/1).

The river basin district is defined as "the area of land and sea, made up of one or more neighboring river basins together with their associated ground waters and coastal waters" (Article 2, paragraph 15). Thus, the river basin management plans are destined to be important tools for implementing the directive. Every plan has to include *a summary of significant pressures and impacts of human activity on the status of surface water and groundwater.* It also requires planning for measures to be taken under exceptional circumstances.

From the hazard perspective, the Water Framework Directive should be seen as a tool that facilitates risk management on the scale of water basins. This dimension should be highlighted in its implementation. At present, there is not enough recognition of the implications of WFD in relation to spatial planning and risk prevention.

6 TERRITORIAL CO-OPERATION: THE SIGNIFICANCE OF INTERREG INITIATIVES

The EU Interreg initiative can be seen as an important channel to develop, apply and test ideas to further ESDP objectives into practice. In the context of risk management, they provide a platform for working with European 'meso-level' governance issues.[13] Interreg programmes can address spatially relevant hazards with transboundary dimensions, helping to overcome the discrepancy between ecological regions and administrative jurisdictions (like the *problem of fit*, see Young 2002). Furthermore, the Interreg initatives provide potential for horizontal networking and information exchange for a wide variety of actors such as regional governments, towns and cities (Thematic strategy on urban environment, 39).

At the moment, however, the potential of the Interreg initiatives is not being exploited for risk prevention. Judging by the declared priorities of the different programmes, it seems that the status of risk management is generally low or negligible[14]. In Interreg III A, only six (6) out of 53 programmes include a clear indication of risk management in their priority wordings. Risks are often mentioned in vague terms in relation to environmental protection. The more deliberate cases focus on forest fires and civil protection (Sardinia-Corsica-Tuscany) and flood-related risks (Mecklenburg-Poland and Euregio Maas-Rhein). In the case of Interreg IIIB, three (3) out of 13 programmes had clear indications of risk management in their priorities. The focus was either on general prevention of disasters (Alpine Space) or floods (North West Europe, CADSES). In the frame of Interreg IIIC, no mention of risk management was found. Where hazards are considered, the focus is often on water resources and floods. (See Table 1.)

Interreg programmes provide space for creative projects on risk management. Cooperation is promising in relation to hazards that cut across specific spatial conditions such as European water bodies and mountain regions. Certain risks are elevated in specific Interreg regions. For example, the North Western Europe Region has an elevated chemical power plant hazard. The South West Europe Region has a strong accumulation of forest fires and droughts, and the Western Mediterranean Region and the Archimed Region have elevated forest fire and tsunami hazards. The entire North Sea and parts of the Baltic Sea Region have a strong to elevated winter storm hazard. Also, relevant hazard interactions should be considered. Some of the Interreg IIIB regions show a strong correlation with certain hazard interactions. The North Sea Region and the Baltic

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[12] See http://europa.eu.int/eur-lex/pri/en/oj/dat/2000/l_327/l_32720001222en00010072.pdf
On the Implementation of the Water Framework Directive, see http://europa.eu.int/comm/environment/water/water-framework/implementation.html

[13] Under Interreg there are cross-border initiatives (IIIA), transnational programmes (IIIB) and interregional programs (IIIC). The transnational Interreg areas are kind of "meso-regions" in Europe – there ten of them in "continental" Europe. http://europa.eu.int/comm/regional_policy/interreg3/abc/progweb_en.htm

[14] Based on a review of Interreg programme priorities at the EU INFOREGIO website, 22 October, 2004. http://europa.eu.int/comm/regional_policy/country/prordn/index_en.cfm?gv_pay=ALL&gv_reg=ALL&gv_obj=13&gv_the=5

Table 1. Risk-related INTERREG III programmes.

Programme	risk focus	Priority wording
Interreg IIIA		
D/PL – Saxony/Poland	reducing pollution and risk	Priority 3: The environment. Plans for the quality of water, reduction of environmental pollution and risks, and protection of nature, the countryside and the climate will guarantee sustainable, overall development in the border area.
D/CZ – Saxony/Czech Rep.	reducing pollution and risk	Priority 3: Environmental development of the area. Plans for the quality of water, reduction of environmental pollution and risks, and protection of nature, the countryside and the climate will guarantee sustainable, overall development in the border area. Cross-border network systems will help make agriculture and forestry more competitive and take advantage of the effects of the common agricultural policy established on the agenda for 2000.
D/PL – Brandenburg-Lubuskie	reducing pollution and risk	Priority 3: The environment. The essential aims of this priority are the reduction of environmental pollution and risks, in view of sustainable, environmentally friendly development in the border area, the protection of residential areas that are close to nature and to natural resources, elimination of abandoned industrial waste and cleansing of watercourses polluted through mining, and the construction of purification plants and waste water treatment systems.
I/FR – Sardinia-Corsica-Tuscany	combating fires, civil protection	Priority 2: Environment, tourism and sustainable development: This priority involves three types of specific objectives: protection and upgrading of the environment, development and promotion of tourism in the border area and sustainable economic development. Among the most important measures covered are cooperation in combating and preventing fires and civil protection, waste treatment and recycling, joint promotion and marketing in the tourism sector and services to SMEs in the field of innovation and technology transfer.
D/PL – Mecklenburg-Poland	catastrophe, disaster & high water protection	Priority 3: The environment. This priority contains measures for the protection of nature and the countryside. Care for the countryside will preserve the attraction of the region's cultural landscapes, secure resources and provide the basis for creating a cross-border catastrophe, disaster and high-water protection facility. Further objectives are the improvement of environmental consciousness and enhancement of the quality of the water in the interior and along the coast.
D/NL/B Euregio Maas-Rhein	floods	Priority 3: Promoting environmental improvement (including agriculture). Key actions concern the improvement of quality of life and the importance of agriculture. Special attention is being paid to overcoming the risks of flooding and the treatment of waste.
Interreg IIIB		
Alpine Space (F, D, I, AUT)	prevention of natural disasters	Priority 3: Smart management of nature, landscapes and cultural heritage, promotion of the environment and the prevention of natural disasters. Key actions focus on good management and promotion of landscapes and cultural heritage, including water resources, and the prevention of natural disasters.
North West Europe (UK, IRL, F, B, NL, LUX, D)	water resources, floods	Priority 3: Sustainable management of water resources and prevention of flood damage. Key actions concern the management of transnational water systems in an integrated and sustainable way and minimizing damage from river and coastal flooding.
CADSES (D, AUT, I, GR)	water resources, floods	Priority 4: Environment protection, resource management and risk prevention. Prevention of natural and human made disasters and risk management as well as projects focusing on integrated water management and the prevention of floods make up the key actions of this priority. This could concern the Danubian area.
Interreg IIIC		
No mention of risk management		

Sea Region (southern parts) are affected by winter storms and storm surge hazards. The combination of earthquakes and landslides is elevated in the southern part of the CADSES Region. The combination of droughts and forest fires are found in the Interreg IIIB Regions, South West Europe, ARCHIMED and CADSES (Schmidt-Thomé 2005, chapter 6).

Transnational Interreg programmes have several interesting projects related to hazards and risk management, such as the CADSES area "Hydroadria" project, monitoring surface and groundwater to detect effects of climate change; North Sea "COMRISK" addressing integrated coastal zone management and the Baltic Sea area project "SEAREG" that deals with climate change induced sea-level rise and coastal flooding.[15] An especially interesting Interreg risk management project is the North West Europe area "ESPACE" project (European Spatial Planning Adapting to Climate Change), which aims at ensuring that adaptation to climate change is recognized and to recommend incorporation within spatial planning mechanisms at the local, regional, national and European levels.

Interreg initiatives are an important resource for developing innovative practices in dealing with hazards. For example, the North West Europe project, COMRISK, is working with Integrated Coastal Zone Management (ICZM) in a cross-national setting and therefore contributing to the implementation of the EU strategy on ICZM (COM (2000) 547 final). The value of Interreg projects is also in how they build bridges between scientific research and the praxis of spatial planners and multiple other stakeholders.

7 PROCEDURAL DEVELOPMENT: TOWARDS INTEGRATED IMPACT ASSESSMENT

Over the recent years, planning and decision-making have become increasingly reflexive through the introduction of different assessment methods such as environmental impact assessment (EIA), social impact assessment (SIA), Strategic Environmental Assessment (SEA), and health impact assessment (HIA). Such methods seek to foresee and prevent harmful development by studying different alternative development paths to identify the best available option.

Environmental impact assessment at the project level and Strategic Environmental Assessment at the programme and policy level are key tools for risk reduction. The purpose of the SEA-Directive (2001/42/EC) is to ensure that environmental consequences of certain plans and programmes are identified and assessed during their preparation and before their adoption. In principle, implementing the Directive provides good grounds for dealing with risks related to spatial development plans. EIA and SEA should be complemented with more specific 'safety impact assessment' (European Commission 2003).

An EU-wide harmonization in dealing with risks based on the EU directive on Strategic Environmental Assessment (2001/42/EC) would be a step forward to the territorial cohesion propagated by the EU. Art. 3 ("The Union's objectives") paragraph 3 of the Proposal for an EU Constitution Treaty pointed out, that the Union *"[…] shall promote economic, social and territorial cohesion, and solidarity among Member States."* (CONV 850/03 from 18.7.2003).

Projects permitted by a certain plan or program might have significant effects on the environment and increase damage potential regarding certain hazards that threaten the area in which the project will be located. The results of a risk assessment can be integrated into the environmental report in which the likely significant effects on the environment due to the implementation of the plan or programme are identified, described and evaluated (Art 5 of the directive). The SEA is well established by legislation and can be described as an existing framework for managing the environment in general and especially risks from natural, as well as technological hazards threatening the environment. This framework would be a great chance for establishing risk assessment and management as an obligatory task within every decision about a spatial plan or programme. Furthermore, it would implement the present EU policy ob-

[15] CADSES project "Hydroadria":
http://www.cadses.net/projects/approved_projects/Hydroadria.html
North Sea project "COMRISK":
http://www.comrisk.org/
Baltic Sea project "SEAREG":
http://www.gsf.fi/projects/seareg/
North West Europe "ESPACE":
http://www.hants.gov.uk/lrt/test/index.html
(also http://www.hants.gov.uk/environment/climatechange/spatialplanning.html)

jectives regarding environmental and civil protection (draft EU constitution treaty and ESDP) (Greiving 2004).

The effective implementation of the SEA directive is crucial to the success of risk management efforts. At the moment, implementation varies considerably over Europe. The adequacy of the SEA processes regarding the objectives of protection of the environment, integration of environmental considerations into the planning process and transparency, will depend largely on the choices that will be made by each Member State when implementing the Directive. The general requirements prescribed by the Directive are not restrictive and leave ample room for creativity, flexibility and adaptability to suit each Member State's context. (Risse et al. 2003.)

The implementation of the Directive may lead to a multitude of systems that have much in common but may also differ on fundamental aspects such as the screening mechanism used to determine if a SEA is required, the public's role, the integration of SEA into the planning process, the weight given to SEA in the final decision and the monitoring approach used for plans of programmes that have been subjected to a SEA. This situation is liable to considerably complicate the European Commission's task when it evaluates the Directive's overall effectiveness in 2006 (Article 12). (Risse et al. 2003.).

Although differences between SEA processes in the European Union may arise, the Directive nevertheless constitutes an important incentive toward the establishment of integrated SEA processes where the public plays a determining role in decision-making and where monitoring is used as a dynamic means for improving the environmental performance of plans and programmes. An important element contributing to the quality and effectiveness of European EIA and SEA and to the potentials of integrated impact assessment, is the development of a spatial data infrastructure under the INSPIRE initiative. If the problems related to data availability and access of spatial information could be resolved, the time and costs for preparing impact assessment reports could be significantly reduced. This would contribute to better and more transparent planning and decision-making. (Vanderhaegen and Muro 2005.)

With the proliferation of different forms of impact assessment, there seems to be increasing receptiveness towards the integration of different kinds of assessments and methodologies under a framework of Integrated Impact Assessment (IIA). As Milner et al. (2005, 60) have noted, there is competition between different strands of impact assessment (environmental vs. social) and thus a need to guard the integrated impact assessment procedure against the domination of a single perspective. As a potential future development, the prospect of integrated impact assessment could facilitate balancing the different kinds of concerns over different dimensions of vulnerabilities to hazards.

8 INTERNATIONAL CO-OPERATION

The Asian Tsunami disaster in December 2004 served as a tragic reminder of the risks of globalization. Together with the staggering numbers of local people who lost their lives in the disaster, a considerable number of European tourists, also lost their lives or were otherwise affected by the disaster. In terms of human casualties, the Asian tsunami became a devastating natural disaster for Europe and Europeans, which, paradoxically, did not take place in Europe. The tsunami served as a reminder that Europe is not isolated from the rest of the world. In the light of the disaster, the European Union needs to continue the co-operation in humanitarian assistance through its organizations such as the European Community Humanitarian Office (ECHO) with international bodies. The EU should continue to cooperate actively within multilateral efforts for disaster reduction and relief. The multilateral organizations and operations of the United Nations are central in this respect.

One of the key processes in this respect is the United Nations International Strategy for Disaster Reduction (UNISDR). A new framework for international cooperation under the UNISDR for 2005–2015 was agreed upon in January 2005 in Hyogo, Japan. Under the Hyogo framework, titled "Building the Resilience of Nations and Communities to Disasters", key areas for developing action for the decade 2005–2015 included the following themes, based on the identification of gaps and challenges in the earlier Yokohama strategy (1994):

(a) Governance: organizational, legal and policy frameworks;
(b) Risk identification, assessment, monitoring and early warning;
(c) Knowledge management and education;
(d) Reducing underlying risk factors;
(e) Preparedness for effective response and recovery.

Likewise, the activities related to the promotion of sustainable development at the international level also require continued attention. The Johannesburg Plan of Implementation of the World Summit of Sustainable Development (August-September 2002) includes the goal of factoring an integrated multi-hazard approach to disaster risk reduction into policies, planning and programming related to sustainable development, relief, rehabilitation and recovery activities.[16]

As climate change becomes a visible topic in the international arena, as seen, for instance in the G8 summit in Scotland in 2005, the EU needs a dual strategy of combining the Kyoto process of climate change mitigation and the more recent focus on adaptation. International exchange of information and joint research efforts should be promoted in this field.[17] Europe has much to offer to the international community, but it also has much to learn from countries that have experiences of living with and learning from hazards.

The effects of globalization constitute a new set of issues relevant for risk mitigation. The socio-economic and ecological changes resulting from globalization that lead to new patterns of vulnerability (like the mega-cities phenomenon) should be better understood, in their spatial distribution as well, so that effective measures could be taken.

9 DISCUSSION: TOWARDS CONSOLIDATED RISK MITIGATION

The growing recognition for the need of a risk management perspective is comparable to the historical evolution whereby the “environment” was included on the EU policy agenda. McCormick (2001) depicts the progression of environmental policy starting from an environmental “awakening” in the 1970s towards the establishment of legal competence in the late 1980s. According to McCormick, EU environmental policy has been in a stage of *consolidation* for the last decade, since 1993 when the European Environment Agency was established. This phase includes a search for a holistic approach and the integration environmental targets into different policy sectors (see European Environment Agency 2005). Interestingly, McCormick argued that the EU still does not have an environmental policy. Instead, it has a series of policies relating to specific environmental aspects such as air pollution, chemicals or waste management.

To follow the parallel of EU environmental policy, the Seveso accident in 1976 provided the awakening momentum to take a major step forward in EU legislation on technological hazards. Similarly, the progress made in the EU’s response towards natural hazards has been accelerated by the major flood and climatic hazard events over the past few years. This implies that risk perceptions are an important factor in risk mitigation.

At present, the EU is moving towards the establishment of legal competence in the field of natural hazards. Since no unified policy exists that addresses hazards in the EU, it can be argued that the policy consolidation phase has yet to come. The EU lacks legislative competence when it comes to natural hazards, which is at issue here. At present, hazards have not found their way into regional development policies nor have they been adequately taken aboard in the development of EU environmental policy. The review of the role of risk mitigation in Interreg initiatives is not very flattering.

The review of European level initiatives indicates that important elements exist for a better inclusion of risk mitigation in EU policies. With the introduction of the notion of territorial cohesion, risk mitigation is moving towards mainstream EU policy. The developments concerning EU cohesion funds during the programming period of 2007–2013 are extremely interesting and very promising since they enable the harnessing of powerful financial instruments to facilitate risk mitigation efforts in the EU.

[16] For a list of multilateral developments in disaster risk reduction, see the annex of the Hyogo Framework document: http://www.unisdr.org/news/OUTCOME-FINAL-as-separate-non-official-document.pdf

[17] A good example of such co-operation was the INDO-EU Workshop on Climate Change & Natural Disasters, in September 06–10, 2004, University of Hyderabad, Hyderabad, India. http://202.41.85.116/indo-eu-ccnd/

This would also mark a new move in public policy concerning hazards towards the use of financial incentives in addition to the traditional "command and control" type instruments. Cohesion funds are also relevant for spatial planning purposes and, thus, the envisaged measures also help integrate risk mitigation and spatial planning.

Time will tell how the EU cohesion instruments integrate risk mitigation objectives to become mainstream practice in member states and regions. It still needs to be clarified exactly how their inclusion in the national programming documents can be guaranteed. The integration could be facilitated through 1) extension of the criteria used to identify a region as eligible for objectives 1, 2 or 3 to hazard or risk relevant criteria (highly sensitive areas); 2) extension of operational programmes to risk relevant projects (projects that decrease the hazard potential and the damage potential or that increase the coping capacity); 3) monitoring in the field of structural assistance focused on environmental effects of the concerned programmes.[18]

The risk mitigation perspective adds a qualitative aspect to cohesion. Economic development may not be merely beneficial, since it increases the economic vulnerability in certain locations, even if it serves to reduce social vulnerability. On one hand, great damage potentials in both human and monetary terms are concentrated in the European cities and urban agglomerations, especially in the "pentagon" area. However, the rapidly growing economies of the new member states require increasing attention. The rapid growth of GDP figures implies that risks might be increasingly taken in relation to environmental precautions. In the new member states, it will be especially important that the EU financing instruments do not contribute to economic development at the expense of environmental protection or social welfare.

The reduction of social vulnerability depends not only on accumulation, but distribution of wealth. Only socially balanced economic development reduces social vulnerability. This also applies in spatial terms, where spatially balanced development is generally less vulnerable to hazards than the concentration of population and productivity around single growth poles (for a broader discussion on vulnerability, Schmidt-Thomé 2005, 77–90). A polycentric, spatially and socially balanced economic development that takes necessary environmental precautions is beneficial for the reduction of vulnerability in Europe.

With a multitude of hazard-relevant actors and institutions, the issues of integration of policies and interplay between actors become crucial. This issue seems pertinent at present, since developments are taking place in the field of risk management. A key principle should be the integration of spatial planning measures and environmental concerns. This integration has seen progress at the EU policy level, but implementation practices in Member States still varies (Clement 2001, Roberts 2001). Such integration is a challenge since spatial development goals have predominantly been based on economic development concerns. This emphasis is still visible in the 3rd Cohesion Report and the ESDP. However, the revision of cohesion policy for the period of 2007–2013 includes new promising priorities for environmental protection and risk prevention. The increasing recognition of the need to address risks in the EU should be accompanied by increasing funding and determination on implementation and monitoring of risk prevention measures through EU instruments.

It needs to be ensured that the instruments are complementary and that resources are not wasted in overlapping work. In Europe the task of coordination is challenging, as no central coordination unit exists. A possible solution to the problem of interplay could be the creation of a European coordination unit similar to the Federal Emergency Management Agency (FEMA)[19] in the U.S. Its mission is to reduce loss of life and property and protect critical infrastructure from all types of hazards through a comprehensive, risk-based, emergency management program of mitigation, preparedness, response and recovery.

Further, the results and developed methodologies of the entirety of ESPON projects can be used and continued in the future to establish a European wide monitoring system to observe spatial risk and its components like natural and technological hazards and economic and social vulnerability.

[18] This attitude has recently changed significantly, but practices in member states are heterogeneous. Exemplary practices have been adopted in some member states such as France and Austria (Barth and Fuder 2002, 67).

[19] The FEMA was founded in 1979 and integrated all former dispersed structure activities in the field of "disaster mitigation".

10 CONCLUSIONS

Moving towards integration and consolidation of risk mitigation in EU policies is a complex task that needs to be pursued at different levels and by different actors.

At the level of guiding principles, increasing attention should be paid to preventive measures addressing natural hazards and patterns of vulnerability. A polycentric, spatially and socially balanced economic development that takes necessary environmental precautions, is beneficial for the reduction of vulnerability in Europe. Both substantive and procedural guidelines and policy instruments should be used.

At the level of EU policy instruments, the use of Structural Funds should be coordinated for risk management, giving assistance to projects that reduce the hazard and/or damage potential or increases the coping capacity. Framing the notion of territorial cohesion from the hazards perspective facilitates the integration of risk mitigation into EU cohesion policy. The effective implementation of the recommendations of the 6^{th} Environmental Action Programme in broadening the scope of the SEVESO II Directive and the implementation of the Strategic Environmental Assessment (SEA) directive should be ensured.

The problem of institutional interplay needs to be addressed to guarantee fluent co-operation between different ongoing initiatives in the field of hazard and risk management, including legislative and financial instruments. The need for a coordinating EU body (European Emergency Management Agency, EEMA) should be considered. Coordination and co-operation is also needed on an international scale, especially in the turbulence of globalization.

At the meso-level of transnational co-operation, national authorities should recognize the upgraded status of risk mitigation in the remodeled cohesion policy for the period of 2007–2013 and include principles of vulnerability reduction and risk mitigation in the programme guidelines. The implementation of the Strategic Environmental Assessment directive (2001/42/EC) should be ensured, broadening the scope of all plans and programmes with potential effects on risk and vulnerability. The use of the Water Framework Directive (2000/60/EC) for integrating land use planning and water resources management in support of risk mitigation should be enhanced. Spatial planning also needs stronger integration with civil protection measures.

As to monitoring and research, a European wide monitoring system is needed to observe spatial risk and its components like natural and technological hazards and economic and social vulnerability. Damage potentials and coping capacities should be monitored at different spatial scales. This effort should use the results of the ESPON programme and should be coordinated with the Infrastructure for Spatial Information in Europe (INSPIRE) initiative. Further study is also needed into the effects of hazards pertaining to issues of globalization as a driving force of vulnerability. This should also include a better understanding of patterns of mobility of European citizens and their relation to hazards.

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