Integration of natural hazards, risk and climate change into spatial planning practices

by

Philipp Schmidt-Thomé

ACADEMIC DISSERTATION

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Supervised by:
Prof. Dr. Veli-Pekka Salonen
Department of Geology
Faculty of Science
University of Helsinki
Finland

Reviewed by:
Dr. Kai Böhme
University of Sheffield, Department of Town and Regional Planning
United Kingdom

Dr. Jonas Satkunas
Geological Survey of Lithuania
Lithuania

Opponent:
Prof. Dr. Michel A. Bouchard
Centre International des Technologies de l'Environnement de Tunis (CITET)
Tunis Carthage, Tunisia

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Dedicated to

my grandfather Paul

and

my father Michael

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Most countries of Europe, as well as many countries in other parts of the world, are experiencing an increased impact of natural hazards. It is often speculated, but not yet proven, that climate change might influence the frequency and magnitude of certain hydro-meteorological natural hazards. What has certainly been observed is a sharp increase in financial losses caused by natural hazards worldwide. Although Europe appears to be less affected by catastrophic natural hazards than other parts of the world, the damages experienced here are certainly increasing. Natural hazards, climate change and, in particular, risk have therefore recently been put high on the political agenda of the EU.

In the search for appropriate instruments for mitigating impacts of natural hazards and climate change, as well as risks, the integration of these factors into spatial planning practices is constantly receiving higher attention. The focus of most approaches lies on single hazards and climate change mitigation strategies. The current paradigm shift of climate change mitigation to adaptation is used as a basis to draw conclusions and recommendations on what additional concepts could be incorporated into spatial planning practices, and for example, multi-hazard approaches are discussed as an important approach that should be developed further. A special focus lies on the definition and applicability of the terms *natural hazard*, *vulnerability* and *risk* in spatial planning practices. Especially risk concepts are so many-fold and complicated that their application in spatial planning has to be analysed most carefully.

This PhD thesis is based on six published articles that describe the results of European research projects, which have elaborated strategies and tools for integrated communication and assessment practices on natural hazards and climate change impacts. The papers describe approaches on local, regional and European levels, both from theoretical and practical perspectives. Based on these, past, current and future potential spatial planning applications are reviewed and discussed.

In conclusion it is recommended to shift from single hazard assessments to multi-hazard approaches, integrating potential climate change impacts. Vulnerability concepts should play a stronger role than at present, and adaptation to natural hazards and climate change should be more emphasized in relation to mitigation. Future spatial planning practices should also consider to be more interdisciplinary, i.e. to integrate as many stakeholders and experts as possible to ensure the sustainability of investments.

Key words: natural hazards, geologic hazards, climate change, vulnerability, risk assessment, spatial planning, Europe

Philipp Schmidt-Thomé
Geological Survey of Finland, Espoo
E-mail: philipp.schmidt-thome@gtk.fi

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LIST OF ORIGINAL PUBLICATIONS

I. Schmidt-Thomé, P., Greiving, S., Kallio, H., Fleischhauer, M., & Jarva, J. 2006. Economic risk maps of floods and earthquakes for European regions. In: Quaternary International 150, p. 103-112.
II. Schmidt-Thomé, P. & Kallio, H. 2006. Natural and Technological Hazard Maps of Europe. In: Schmidt-Thomé, P. (ed.) 2006. Natural and Technological Hazards and Risks in European Regions. Geological Survey of Finland Special Paper 42, 17-63.
III. Schmidt-Thomé, P. & Peltonen, L. 2006. Sea level Change Assessment in the Baltic Sea Region and Spatial Planning Responses. In: Schmidt-Thomé, P. (ed.) 2006. Sea level Changes Affecting the Spatial Development of the Baltic Sea Region. Geological Survey of Finland, Special Paper 41, Espoo, p. 7-17.
IV. Klein, J. & Schmidt-Thomé, P. 2006. Impacts and Coping Capacity as key elements in a Vulnerability Assessment on Sea Level Change Scenarios. In: Schmidt-Thome, P. (ed.) 2006. Sea level Changes Affecting the Spatial Development of the Baltic Sea Region. Geological Survey of Finland, Special Paper 41, Espoo, p. 45-50.
V. Schmidt-Thomé, P., Viehhauser, M. & Staudt, M. 2006. Climate Change Impacts on Sea Level and Runoff Patterns: Application of a Decision Support Frame for Spatial Planners in case study areas. In: Quaternary International 145/146, p. 135-144.
VI. Schmidt-Thomé, P., Staudt, M., Kallio, H. & Klein, J. 2005. Decision Support Frame to Estimate Possible Future Impacts of Sea Level Changes on Soil Contamination. In: Lens, P., Grotenhuis, T., Malina, G., Tabak, H. (eds): Soil and Sediment Remediation: Mechanisms, Technologies and Applications. Integrated Environmental Technology Series, London, p. 409-417.

In Paper I Philipp Schmidt-Thomé equally contributed to the development of hazard and risk methodologies and was responsible for drawing the conclusions. In Paper II Philipp Schmidt-Thomé was responsible for the development of the larger share of the methodologies and responsible for the descriptions of the hazards and the interpretations of the results. In the Papers III and IV both authors are equally responsible for the development of the methodology. In the Papers V and VI Philipp Schmidt-Thomé was responsible for the development of the methodology and equally responsible for its application in Gdansk and the analysis of the results. Philipp Schmidt-Thomé prepared all of the manuscripts I-VI and was responsible for communication with the reviewers as well as the editors.

INTRODUCTION

Natural hazards have always played an important, if not to say vital, role in the development of societies and cultures. They have always posed threats to human beings and their assets and they have often lead to catastrophic disasters. Some of these disasters are very well documented (e.g. Pompeii), meanwhile others can only be detected by geological evidence, for example tsunamis in India (Chandrasekar et al. 2006). Some natural catastrophes are based on myths, for example the biblical flood, and have not been proven. Despite real or imagined threats to a settlement or a society, human beings have continued to dwell and settle in naturally hazardous areas, putting their lives and assets at risk. Often risks have been assumed deliberately, despite experiencing several disasters and continued threat of natural hazards. Many such settlements have developed into culturally and economically important cities over the centuries. Examples of large cities that have been recently severely affected by natural hazards can be found from all continents, such as Prague (floods in 2003), Kobe (earthquake in 1995), Canberra (bush fires in 2003), San Salvador (earthquake and landslide in 2001) and New Orleans (hurricane in 2005).

The reasons that human beings settle in hazardous areas are many. One aspect is that some areas, which possess certain natural advantages that attracted the initial settlements, are also threatened by natural hazards. Natural hazards can even be the reason for local advantages (e.g. fertile soils in volcanic areas or floodplains), and hazards themselves were not recognised, or were underestimated, until it was too late and catastrophes occurred. Many natural hazards rarely result in disasters in the human timescale, so that the real threat is often recognized too late, or has been deliberately taken as the other advantages of the settlement areas prevailed. Until the 20th century, and sometimes still today, natural hazards are thought of an "act of god", a term still used in liability claims (Kusler 2004). Kusler argues that nowadays, when natural hazards are better understood and prediction is improving, the term "act of god" is losing its justification. However, many settlements have grown to such an extent that relocation into less hazardous areas is not an option. Also, often there was, and still is, a belief that science and technology could one day help forecast and/or remove natural hazards completely. The fact is that most natural hazards cannot be fully mitigated and, besides evidence-based definition of potentially hazardous areas, are still impossible to predict, at least on a long to mid-term perspective. Therefore, the understanding is growing, forced in part by political considerations, that hazard mitigation should be incorporated into spatial planning (e.g. United Nations 2004). Financially oriented actors, and increasingly also government expert groups, stress that since natural hazards cannot be avoided, more efforts should be put in vulnerability reduction and hazard adaptation (e.g. Marttila 2005, Munich Reinsurance Company 2004).

Settlements affected by natural disasters have rarely been relocated from naturally hazardous areas, but tend to be rebuilt in close vicinity or on top of the ruins of earlier disasters. Nowadays hazards, their source, potential magnitude and probable return periods are better understood, but nevertheless people remain in hazardous areas, often despite improved knowledge. The reasons for not leaving or giving up settlements and dwellings are many. Besides the natural advantages of certain hazardous areas, traditional aspects are a reason for staying, for example people being deeply rooted in an area. Financial issues also play an important role, as many traditional and new settlements have certain strategic advantages (natural, trade, military, etc) that are not easily found elsewhere. Also, giving up existing, functioning settlement structures is very costly and a potential natural hazard is thus perceived less problematic in comparison with a total relocation (e.g. Lomnitz 1974).

Examples of a total, sustainable, relocation of long existing settlements due to a potential threat by natural hazards are rarely found in human history. For example the capital of the Central American State of El Salvador, the city of San Salvador, was relocated to Santa Tecla after an earthquake in 1854, but was returned to its original location in 1895, mainly because of the lack of public support. Based on this experience, a relocation of the capital of Nicaragua, Managua, was assessed but not recommended (e.g. Lomnitz 1974). Instead of relocation plans, geological site studies are used for earthquake proof construction to support local city planning in Central American (e.g. Schmidt-Thomé 1975). There are certainly other examples of relocation practices, but often several other reasons for a relocation of settlements, in addition to natural hazards, were equally strong. For example, the relocation of settlements and people from areas subject to drought in Laos allegedly had political motivations (Petschel-Held 2001). Relocation of settlements is a sensitive issue, both on the political and resident side and is difficult to manage (Napier & Rubin 2002), even though the Economic Council of the United Nations recommends relocation of vulnerable buildings in flood prone areas (United Nations 2000). Relocation might seem to be the safest way to avoid natural hazards, but the impact of the relocation process on the lives of citizens is dramatic and challenging to manage. There are several examples of unsuccessful relocation attempts (e.g Perry & Lindell 1997). Although Italy is a country where relocation from hazardous areas is enforced by planning law, in practice few relocation activities occur (Galderisi & Menoni 2006).

This study analyses the use and application of natural hazard information, and the potential impact of climate change on those, in spatial planning practices. The study goes beyond the display of hazards in maps for planning purposes. It concentrates on communication processes, keeping in mind that the visualisation of territorial extents of hazards and threats is a useful tool that is to be handled with great care. The target of this study thus lies on the kind of information that planners and other stakeholders require when discussing natural hazards and climate change impacts and how this information should be used in the communication processes. A broad understanding of hazards and their potential impact on spatial development is vital in the discussion of mitigation and adaptation.

The terms *stakeholders* and *spatial planning* are explained in more detail in the chapter *Purpose of this study* below.

The study is based on six published scientific articles which summarize the research results of European scientific projects on the subjects of hazards, risk and climate change impacts. The study starts with an introduction to the role of natural hazards, and climate change, in the living environment. It then analyses spatial planning practices and their development. The results are introduced with a summary of the six published articles, which is followed by a discussion of the practical applications of hazard, risk and climate change data in planning practices.

THE ROLE OF NATURAL HAZARDS, RISK AND CLIMATE CHANGE IN SPATIAL PLANNING

Natural hazards and spatial planning

The integration of hazard related topics into planning started with disaster relief regulations approximately 30 years ago (e.g. Anderson et al. 2003). Since the 1980's natural hazard mitigation started to be integrated in spatial planning in developed countries, which then led to a world wide approach, for example the UN proclamation of the International Decade for Disaster Reduction in 1990 (Quarantelli 1995). Despite this international initiative, the consideration of hazards and risk mitigation in planning policies remains rare (UNDP 2004). The importance of spatial planning in risk management has been understood and implemented more vigorously since the mid 1990's (e.g. Burby 1998, Godschalk et al. 1999). One of the first national acts on planning, hazard and risk was signed in the United States of America in 2000 (Disaster Mitigation Act, 2000).

In the 1990's, natural hazard and risk considerations began finding their way into planning in Europe (e.g. Fleischhauer et al. 2006), but many countries still lack clear guidelines on how to deal with hazards and risk on a spatial planning level (e.g. UNDP 2004). At the EU level, the European Spatial Development Perspective (ESDP 1999), the European Conference of Ministers Responsible for Regional Planning (CEMAT 2003), the EU working group on Spatial and Urban Development (SUD 2003) call for the integration of hazards and risk in EU regional policy. The European Commission underlined that the European Structural Funds 2007–2013 should be linked to risk prevention and stressed that an integrated approach on risk management is required at the EU level (European Commission 2004, 2006).

There are several, mainly economic, reasons for this recent stronger focus on natural hazards and planning. From a global perspective, the insured losses due to natural hazards have been rising in the past decades, with a large increase in losses in the last years (Munich Reinsurance Company 2004). An analysis of natural hazard related financial loss data reveals that there has been an increase in both catastrophic events and insured losses since the 1960´s. However, looking back over the last two decades it can be seen that the dramatic increase of financial losses is not reflected to the same extent by the increase of (reported) catastrophic events or loss of human lives (e.g. Emergency Disasters Database 2006). Therefore it is probable that the trend of increasing financial losses is a result of an increase in the total number of catastrophes that were actually reported. Data before 1980 are not as accurate as more recent data (e.g. UNDP 2004). Also, the insured losses have increased sharply due to steadily rising market values of insured goods and assets. In other words, there might be an increase in catastrophic natural hazards, but the dramatic increase in losses is also due in part to economic growth. There has been a strong increase in the number of people affected by disasters, which is also due to the increase of the world's population. On the other hand, the number of fatalities in natural disasters has not risen over the last 100 years. Even in 2004 (the year in which the tsunami disaster in the Indian Ocean occurred) has not reached the highest recorded number of fatalities (Emergency Disasters Database 2006). In this analysis, it must be taken into account that there are no complete and coherent data sets covering all natural disasters and their effects.

The media has often used the records of increasing financial losses as an indication for the impacts of climate change (e.g. Spiegel Online 2006, Deutsche Welle 2006). Indications for an increase of natural hazards are often derived from the comparatively high number of extreme flood and storm events in recent years (e.g. Munich Reinsurance Company 2004). Though there is no doubt that the climate is changing, the question remains as to what extent the occurrence or magnitudes of natural hazards are already influenced by this process. There are indications that climate change might lead to an increase in extreme weather events, or hydro-meteorological hazards, but as yet there is no statistical proof of this (e.g. Church et al. 2001, Bärring & Persson 2006, Rahmstorf & Schellnhuber 2006). Along with the discussion concerning extreme events, there is an ongoing debate on climate change effects and potential mitigation strategies, such as the Kyoto Protocol. Journalists sometimes appear to deliberately modify the scientific contexts given by climate researchers in order to link climate change to natural hazards without scientific evidence. This suggests that good headlines count more than good evidence (e.g. related article in Die Zeit 2005).

For example, many media contributions attributed the extreme winter storm "Erwin/Gudrun" that occurred in the Baltic Sea in 2005 and the flooding of New Orleans by the Hurricane "Katrina", among several other natural phenomena or disasters, to climate change (e.g. Deutsche Welle 2006, Spiegel Online 2006, The Time 2005). It might rather be that these two storms in particular were extreme weather events, as there are conflicting analyses of hurricane trends and their links to climate change. Trends of increasing magnitudes, for example in tropical cyclones, have been suggested (e.g. Emanuel 2005, Mann & Emanuel 2006) but the time series are not yet long enough for definite conclusions to be reached (Trenberth 2005). Nevertheless, the prominent news coverage on, for example, hydro-meteorological hazards and extreme events could easily lead a layman to connect climate change effects to both storm frequency and intensity (e.g. Die Zeit 2006).

The increase in financial losses due to natural hazards is thus often attributed to climate change with mono-casual explanations. Instead, other factors should also be assessed in the discussion. For example, the effects of globalisation, in particular the concentration of capital and the growing dependence on mobility, lead to an increase of losses in case of natural catastrophes (McBean & Henstra 2003). This indicates that a greater involvement of stakeholders into the process of understanding and dealing with the sources and effects of natural hazards and the financial implications, as well as the potential effects of climate change on natural hazards, is very important.

One aspect of why natural hazards have not played an important role in spatial planning in European countries is probably the fact that other parts in the world appear to be more severely affected by natural hazards than Europe. This seems obvious when comparing the total number of casualties and financial losses due to natural catastrophes that occurred since the 1950's per continent. In comparison to the large number of disasters and people affected or killed in Africa, the Americas and Asia, the European continent is affected by natural hazards to a far lesser extent (Emergency Disaster Database 2006). But the impression of a less affected continent is true only at a first sight. When a region is hit by a disaster, the total number of casualties and the magnitude of the losses has to be seen in the context of the respective regional or national statistics and not on a continental or global scale. When a hazard strikes a region that is not used to such an event, it might cause unanticipated damages of all kinds (e.g. UNDP 2004). It is therefore necessary that the local, regional or national extents of natural hazards are assessed on an appropriate scale in order to avoid losses and potential long lasting effects, for example on the tourist sector. Historically, several natural catastrophes have actually occurred in Europe, but many of these have been forgotten from the collective memory. Tsunamis, for example, have not played an important role in European thinking recently, not even when the Balearic Islands were struck by one after the Algerian earthquake in 2003 (Hébert, 2003). Fortunately this tsunami was only 1.5–2m high and damage was limited to some boats in harbours. This tsunami was not mentioned in the European news media, despite the fact that the last tsunami disaster in Europe had occurred less than 100 years before in 1908 in Messina, causing over 50 000 casualties. The news coverage of the 2003 tsunami might have been far greater had it occurred after the tsunami of the Indian Ocean in 2004, and the calls for Mediterranean tsunami early warning systems might be a lot stronger than they are at present.

Climate change and spatial planning

The potential effects of climate change on the magnitude and the frequency of natural hazards is currently a topic that is of great concern to scientists and stakeholders alike (e.g. Schellnhuber et al. 2006). Therefore this study not only focuses on the integration of natural hazards in planning practices, but also on the effects that climate change can have on natural hazards and how this information, which is based on scenarios, can be used in decision making processes.

Climate change has only recently been incorporated into spatial planning, for example in the United Kingdom the term "sustainable" was integrated into planning during the 1990's (Bulkeley 2006). Climate change is mainly integrated into planning in the form of mitigation strategies, i.e. by focussing on greenhouse gas emission reduction in general or the role of traffic in particular (Robinson 2006, Levett 2006).

Climate change adaptation is starting to receive attention in spatial planning. In The Netherlands, which has started to integrate climate change into planning in this century, the focus is starting to shift from mitigation to adaptation strategies (Vries 2006). There are several national strategies and calls for the integration of climate change, and a positive trend is that several cities or regions have taken actions on their own to deal with climate change impacts (e.g. Marttila et al. 2005, United Kingdom 2006). Peltonen et al. (2005) give a series of recommendations to integrate climate change adaptation into urban planning. One concrete example of a town taking a decision related to climate change research was made by the Town Government of Pärnu (2006). It was decided to postpone proposed ground surface raising activities in order to take the results of climate change impact studies into account when designing flood protection measures.

Integrated multi-hazard approaches

Even if the awareness of natural hazards and associated risks is constantly rising and spatial planning is increasingly integrating hazard and risk management, the scope of most of these activities is limited as they focus on selected single hazards. An integrated multi-hazard approach is still rare. Among the planning systems of the eight European countries analysed by Fleischhauer et al. (2006) only France takes all spatially relevant natural (and technological) hazards into account in the planning system. Other countries consider only the most prominent hazards, some propose that all hazards should be taken into account at some latter stage (e.g. Federal Office for Spatial Development 2006). Other policies on natural hazards deliberately exclude certain hazards (Shoalhaven City Council 1990), which is also the case for some recommendations at the European scale (e.g. Lilljequist & Ligtenberg 2005). The reason for excluding certain hazards from policy recommendations and planning guidelines is not known. In some cases it might be that authorities were somehow forced to respond quickly to a recent catastrophe, for example floods, but the focus was not widened. Other reasons might include the lack of time and appropriate information to cover all potential hazards. Partly there might also be political reasons to exclude certain hazards. A public discussion might reveal how risks have been taken deliberately, for example by continuing to allow housing development in potentially flood prone areas.

In most of the examples of hazards and risks integrated in spatial planning that were reviewed in this study, only the most obvious natural hazards were so far taken into account in planning. Many other hazards, some of which can lead to an even greater amount of casualties and financial losses than the ones considered, are not yet incorporated (see also Wanczura 2006). A focus on only the most prominent natural hazards, or the most recent event, can be dangerous, as many potential threats to spatial development are not assessed. It should therefore be of great importance to analyse all potential natural hazards that can affect an area when drawing up spatial planning guidelines.

One example of an integrated multi-hazard approach has been developed by Anderson et al. (2003) for Massachusetts. Here, the natural hazard mitigation by planning includes a comprehensive checklist of hazards that occur in Massachusetts, leaving extra space for adding additional hazards.

An integrated approach to defining all hazards that are spatially relevant is a challenging task. The German Advisory Council on Global Change developed an example for a global risk analysis (WBGU 1998). This report tries to integrate all types of global environmental risks, meanwhile natural hazards are represented by a few examples only. The ESPON 1.3.1 hazards project used the risk schemes developed by the WBGU to identify all natural hazards that concern spatial planning. Eleven natural hazards (and four technological hazards) were specified as spatially relevant (Fleischhauer 2006). All hazards were mapped individually on a European scale. They were also combined into aggregated hazard maps and subsequently with vulnerability patterns. This work represents the first integrated approach to hazard and risk analysis that potentially affect the European territorial development (Paper II, see also summary below and table 1). Certainly, the approach should be developed further and applied on different scales, as the overview on the entirety of potential hazards allows a rather objective analysis on their potential effects on spatial development. Once the whole array of risks is studied, the focus can be placed on the most imminent threats. Nevertheless, it is important that the selection of hazards is done in comprehensive and integrated manner.

Examples of natural hazards that are already emerging along with climate change include storm surges, extreme temperatures and droughts. The sea levels are rising, not only according to climate change scenarios but also according to gauge measurements, and the rise in sea level has a direct influence on changing the boundaries of coastal flood prone areas (e.g. Church et al. 2001, Klein & Staudt 2006, Meier et al 2006, Papers V & VI, Staudt et al. 2006). This can lead to environmental problems, such as soil contamination and seawater intrusions into groundwater aquifers (e.g. Paper VI, Staudt et al. 2006). In the case of droughts, most climate change scenarios propose an increase of dry spells, and the 2003 heat wave over large parts of Europe could be attributed to climate change (Bärring & Persson 2006, Rahmstorf & Schellnhuber 2006).

There has been recent increase in the discussion of the potential impacts of climate change, which resulted in the consideration of climate change in the political decision-making process and spatial planning (Campbell 2006). Examples at the EU level include the European Conference of Ministers Responsible for Regional Planning (CEMAT), which clearly states that among the numerous processes that are challenging the sustainability of future development in Europe are the effects of climate change (CEMAT 2003). Also the European Spatial Development Observation System (ESPON) outlined that the effects of climate change play a vital role in European regional development (ESPON 2002). Several strategies on climate change are being developed and implemented at the European national government level, such as examples from Finland (Honkatukia 2001), Germany (Höhne 2005), Latvia (Department of Environmental Protection 2006), Lithuania (Konstantinaviciute 2003), and The Netherlands (Vries 2006). Most of these strategies focus on climate change mitigation (e.g. greenhouse gas emission) and seldom incorporate the impacts of associated natural hazards.

There are some good recent examples of identifying the effects of climate change and discussing adaptation strategies. The United Kingdom is undertaking efforts to acquire better knowledge of climate change impacts, mainly by supporting research and installing expert groups. This is intended to lay the scientific basis for future decisions (United Kingdom 2006). A German document also discusses climate change impacts and focuses on adaptation strategies, stating that a special working group on this matter shall be installed under the Federal Environment Agency (Weiß et al. 2005). One of the most comprehensive approaches on climate change adaptation is probably found in Finland. Based on a decision of the Finnish Parliament in 2001, the Ministry of Agriculture and Forestry developed a national climate change adaptation strategy (Marttila et al. 2005). This strategy analyses the potential impact of climate change on several sectors and their sensitivities and recommends research activities. The simultaneously launched FINADAPT project developed climate change scenarios and discussed their respective impacts. This work has been documented in fifteen sectoral reports, many of which contain direct recommendations on adaptation strategies (FINADAPT 2006). One of these reports focuses specifically on urban planning and concludes, among others, that vulnerability patterns are the key to understand the potential impacts of climate change. It recommends taking into account the spatial dimension of climate change impacts and that in the context of regional development, risk based approaches should be developed for spatial planning. The development of risk-based planning methods should include several actors and stakeholders, also from the public, improve sectoral cooperation, and incorporate climate change criteria into environmental impact assessment and strategic environmental assessment processes (Peltonen et al. 2005).

Problematic aspects that are often brought up when it comes to integrating climate change into planning are the uncertainty and the long time span of the models, as well as the problem of downscaling the climate change models for appropriate use on local level (Paper III, Halsnæs 2006). Despite these concerns, several planners involved in the projects that form the basis of this study have expressed their strong interest in integrating climate change into their planning practices, especially in connection with future land use. This is because the sustainability aspect was considered more important than the fact that political decision making is often made on short term interests (e.g. Virkki et al. 2006). While planning can do rather little on the climate change mitigation side, its role on climate change adaptation side can be substantial (e.g. Vries 2006).

Many countries that are discussing national strategies on climate change focus only on the most prominent hazards, and many less frequent or recently emerging hazards (e.g. extreme temperatures) are seldom mentioned. However, there are a few countries that are clearly asking for a review of all potential hazards (e.g. Anderson 2003, Fleischhauer 2006b). Integrated multi-hazard and climate change approaches are still rare. The main focus of planning and climate change impacts is on river and marine floods. Other natural hazards may eventually be mentioned but are not incorporated into local and regional assessments (e.g. Vries 2006, Bulkeley 2006, Federal Office for Spatial Development 2006).

Climate change might have impacts on all so-called hydro-meteorological hazards, and also some geo-hazards. Natural hazards are often distinguished into geo-hazards and hydro-meteorological hazards, but there are no exact definitions, as natural hazards are split up into different groups and defined differently in several scientific, planning and policy related documents (e.g. Lilljequist, R. & H. Ligtenberg 2005, Anderson 2003, Federal Office for Spatial Development 2006, McBean & Henstra 2003, Masure 2001). This study uses the definition of hazard that was developed during two EU research projects, and is discussed in the chapter on terminology below.

QUESTIONS

A review of several approaches seen in policy recommendations and implemented planning guidelines has shown that natural hazards are more and more integrated into planning practices but that both the terminology in use and the number of considered hazards vary greatly, over both the European continent and also internationally. Therefore many questions still need to be answered in this field.

This study focuses on the following set of questions: What are the main challenges and opportunities for planning guidelines to support planners in taking up all natural hazards that potentially threaten an area? How can the potential impacts of climate change be integrated in such approaches? What are the most appropriate forms of analysing and displaying spatially relevant natural hazards and risks and what are appropriate stakeholder communication processes?

PURPOSE OF THIS STUDY

The purpose of this study is to derive conclusions from the set of published scientific articles (Papers I–VI) and to develop further approaches on how to identify, analyse, display and communicate natural hazards to stakeholders and to support spatial planning and sustainable regional development. A special focus lies on the integration of the potential effects of climate change on natural hazards. The study was developed from a European perspective, taking several case study experiences from European countries, but the focus is international. The projects that form the basis of this study have received positive European and other international feedback and response, mainly from East and South East Asia where natural hazards have a large impact on spatial development.

Stakeholders are here defined to be all persons involved, interested in and affected by spatial planning. Besides the spatial planners themselves, these include other authorities, decision makers and land owners, as well as the interested and concerned public. This definition respects the call for integrated hazard and risk assessment approaches (e.g. UNDP 2004). Spatial planning is a generic term that refers to various kinds of planning practices that influence or aim to influence spatial patterns, i.e. the location and vitality of different activities, and is defined from a European perspective: "Spatial planning refers to the methods used largely by the public sector to influence the future distribution of activities in space. It is undertaken with the aims of creating a more rational territorial organisation of land uses and the linkages between them, to balance demands for development with the need to protect the environment, and to achieve social and economic objectives. Spatial planning embraces measures to co-ordinate the spatial impacts of other sector policies, to achieve a more even distribution of economic development between regions than would otherwise be created by market forces, and to regulate the conversion of land and property uses." (European Commission 1997, p.24). European planning professionals and researchers frequently use this definition, both locally and internationally. It helps to discuss planning matters without having always to specify the planning level or spatial scale (e.g. Böhme 2002). Since this study focuses on hazards, risk and climate change related communication and integration into planning, it would go beyond the scope of this study to address all particular planning levels separately. Instead, it addresses hazard and climate change related planning practices in general. If the conclusions of this study should be applied in a country or a region, the respective planning authorities are to decide at which level of planning these might be integrated. The terms hazard, vulnerability and risk are discussed and defined in detail in the discussion chapter.

MATERIAL AND METHODS

This study is based on research results that were obtained from several EU research projects conducted under different funding platforms. Most of the results of these projects have been peer reviewed and published in international scientific journals, some results are still being reviewed or are further developed in follow-up projects. The two most important projects that have delivered results used in this study are the European Spatial Planning Observation Network (ESPON) thematic project 1.3.1 on natural and technological hazards (further referred to as ESPON Hazards project). And second the "Sea level change affecting the spatial development in the Baltic Sea Region" (SEAREG) project conducted under the Baltic Sea Region INTERREG IIIB programme. Both of these projects were completed between 2002 and 2005.

The data used to produce the maps and statistical analyses used in the publications were mostly free of charge since the projects had not allocated funds for purchase of data.

The ESPON Hazards project data were collected from several international sources, with agreements that enabled their free use. The data sources are indicated on the respective maps (Paper II). The data were entered into geographical information systems (mainly ArcGIS) for statistical calculations, spatial analyses and the development of typologies. The aggregated hazards and risk maps are based on questionnaires filled out by European experts who weighted the spatial importance of a hazard from a European perspective on spatial development (Paper II, Olfert et al. 2006).

The climate change scenario data used in the SEAREG project was downscaled from IPCC scenarios, and the resulting sea level changes were calculated by the project team (Meier et al. 2006). The case study topographies were obtained by the purchase of data (Stockholm), allowance to use data free of charge (Pärnu) and digitalisation of topographic maps during the project (Gdansk). The storm surge data came from local experts. Usually average storm surge heights were used to obtain moderate scenarios and avoid extreme cases. In all cases, GIS was used to calculate spatial distributions and plot resulting scenario maps. The vulnerability assessments were developed during the project (Paper IV) and applied during interviews and assessments with local experts (Paper V and VI).

Research results from the SEAREG follow-up project "Developing Policies and Adaptation Strategies to Climate change in the Baltic Sea Region" (ASTRA), as well as the "Applied Multi Risk Mapping of Natural Hazards for Impact Assessment" (ARMONIA) project of the Sixth Framework Programme of the EU are also used in this study. Research results from other EU and international research activities are reviewed, interpreted and quoted accordingly. Best practice examples are analysed in order to identify potentials for further development and applications in other regions.

All approaches discussed in this study were developed in close cooperation with planners and other stakeholders in order to ensure the applicability of this research work to spatial planning practices. The results will demonstrate how natural hazards, climate change impacts and vulnerability patterns are currently used in spatial planning practices and how this usage could be expanded and/or improved.

RESULTS

The following section summarizes the results of the scientific papers used for this study. The papers are further analysed and discussed in this study, with reference to other research results or papers.

The first part summarizes two papers on the development of pan-European scale hazard and risk maps on a scale that supports the development of cohesion policies and regional development policies and appropriate funding structures.

The second part summarizes four papers on the development of a decision support frame that supports planners, decision makers and other stakeholders in developing strategies on climate change adaptation and impact mitigation.

Part 1 European hazard and risk maps

Paper I

This paper contains initial results on risk maps published from the ESPON Hazards project, describing the development of risk maps derived from flood and earthquake maps of European regions. Since there are many different definitions of risk (see discussion below) the ESPON Hazards project chose one of the most widely used risk definitions: risk is a function of the hazard (probability) and the vulnerability (extent of damage). Since very few data were available on these risk functions during the starting phase of the project and the methodology was still under development, rather general variables of vulnerability were chosen, *population density* and *GDP per capita*. Since the objective of the project was to cover all of Europe, and to define risk from a European perspective, the vulnerability was defined to be highest in areas with a high population density and a high GDP per capita. Consequently, the vulnerability decreases with a lower population density and a lower GDP per capita. The assumption is, that the risk to development in the EU is higher if a rich and densely populated region is struck by a hazard than in the case of a less populated and less rich region. If, for example, London or Paris were damaged by a natural disaster, the consequences for the entire European continent would probably be greater and longer lasting than in the case of a hazard impacting a remote, rural area. This definition of vulnerability and risk does not take into account the regional impact, which might be devastating in any case, but it sketches a risk pattern over the entire European space.

Since the risk is a function of the hazard and the vulnerability, it was decided to use a complex legend that allows the differentiation of the risk according to the respective hazard and the vulnerability factor. The map displays nine risk classes and colours, but the shades of the colours allow distinguishing between twenty-five classes, depending on the influence of the hazard and/or the vulnerability, respectively.

The maps can be used, for example, to debate about funding and development support, as currently low risk areas might increase in risk if the GDP and the population density would rise. The interesting
ures behind these patterns are the hazard and vulnerability classes, because some regions might show a high risk due to a high hazard potential, meanwhile other regions show a high risk because of a high vulnerability. The analysis and debate could thus focus on, e.g. the necessity of further developing areas that already have a high risk due to a high hazard. In other words, it might be considered to concentrate economic development in areas that have a low hazard potential. It is also possible to connect development programmes with the corresponding and appropriate hazard mitigation measurements, or, even more appropriate, with adaptation.

Since the ESPON Hazards project received substantial criticism for basing the risk on only two functions, the maps were re-named as economical risk maps and further integrated risk maps were developed. These are described in the Paper II on natural and technological hazard maps of Europe.

Paper II

This paper presents the final results of the ESPON Hazards project on mapping the natural and technological hazards and risk that affect the spatial development on a European scale. The objective of the mapping was to identify all hazards and risks that are spatially relevant (Schmidt-Thomé 2005, Fleischhauer 2006) and display those covering the entire ESPON space (25 EU member countries, the accession countries Bulgaria and Romania as well as the associated countries Norway and Switzerland). It was decided to use only such data sets that were available for the entire territory in order to maintain comparability with the results of other ESPON projects. All ESPON results were reported on a regional scale, the 3rd level of the Nomenclature of Territorial Units for Statistics (NUTS

3). Since natural hazards do not respect political boundaries, this approach does not delineate the exact extent of natural hazards, but displays the entirety of affected regions. It thus shows the areas that may be only marginally affected by hazards and the respective regional political and planning responsibilities. It has to be kept in mind that this approach both exaggerates and minimises the actual territorial extent of hazards, as it focuses on an overview of the extent of hazards from a European (regionalised) perspective.

The paper describes the mapping approach for each spatially relevant natural and technological hazard on a single map and the analyses of the extent of each hazard over Europe. A division into five hazard classes from very low to very high is used to enable a later aggregation of hazards. Since not all hazards affect the European territory equally, it was necessary to weigh the hazards before they could be aggregated. To this goal, a weighting system was applied using several hazard and planning experts to identify the importance of each hazard from the perspective of European spatial development (see also Olfert et al. 2006). The weighted hazards were then aggregated into five classes and displayed according to the respective percentiles on NUTS 3 level. The aggregated natural hazard map (Schmidt-Thomé 2005) shows that the highest density of high natural hazard classes is located in areas of highest population density and high GDP per capita: In central Europe, the French Mediterranean coast, parts of the Iberian Peninsula and parts of eastern Europe. There are only few areas of low or very low natural hazards. These are found in larger parts of northern Europe, as well as in parts of France and Spain. The paper presents an aggregated natural and technological hazards map, showing a pattern similar to that of the aggregated natural hazard map. The similarity is partly based on the fact that the technological hazards are represented only by four examples. Further, the main change in the aggregated natural and technological hazard pattern is that western Europe is characterised by more very high and high hazard areas, whereas these higher hazard classes decrease in eastern and southern Europe.

The vulnerability perspective that was used for the aggregated risk map was further developed from that described above (Paper I), into a so-called integrated vulnerability that takes more facts than GDP per capita and population density into account. Kumpulainen (2006) discusses several international vulnerability concepts relevant for spatial development and hazards. The proposed integrated vulnerability map on a European scale could not be developed, due to the lack of sufficient, comparable data. A more preliminary approach was used instead, in which the integrated vulnerability is represented by four variables in five classes. (Kumpulainen 2006).

The aggregated hazard data were then combined with the integrated vulnerability in order to produce the aggregated risk map. This risk map shows a similar pattern as the aggregated hazard map: The areas at greatest risk in Europe are concentrated in the area of highest GDP per capita and population density, the so-called "Pentagon" of Europe.

The application of the hazard and risk map concepts with political and regional development perspectives depends on the needed accurateness. Since the maps are based on a regionalised perspective of the European territory, they display an integrated overview of the distribution of hazards and risks. One key objective of the EU is to support balanced and sustainable development, aiming at evening out substantial economic and social differences between European Regions (Article 2 of EU treaty 2002). As the EU regional policy instruments encourage investment, proper information on hazards and risk helps to avoid wasteful spending of European funds. The maps presented identify the main hazard patterns that affect the continent in order to help define which type of fund allocations might be appropriate in each region. Tarvainen et al. (2006) have identified hazard agglomerations and clusters of hazard densities for the development of regional hazard typologies. These can be further overlain with, for example, European Regional Development Fund (ERDF) programme areas, the so-called INTERREG regions. Schmidt-Thomé et al. (2006) have applied this information to single hazard maps in a report that supports future regional development fund structures. This report contains a database on hazard related projects of all INTERREG regions and programme strands. These data are combined with the hazard maps to help identify areas that have particular hazard patterns and those areas, which have not yet implemented respective hazard related projects.

The aggregated hazard map is mainly to provide an overview, as the aggregation was done with a weighting process and is thus strongly dependent on expert opinion. Different weighting approaches might lead to varying results. The approach is valuable though, as it represents the first approach on how to aggregate hazards on a continental scale, and provides an indication on the advantages and disadvantages of the chosen method.

The aggregated risk map gives an interesting overview on the risk pattern in Europe, but it is not without its problems. It is a very challenging task to identify a definition of vulnerability that is widely accepted. Also, the scientific basis for the development of risk maps is still evolving and not yet agreed upon (e.g. Cutter 1996, Schmidt-Thomé et al. 2006a). As with the weighting of the aggregated hazards map, it is challenging to assess risk from a European perspective, because most experts tend to take certain, personally well known, regions as the basis for their assessment. These challenges make it problematic to use the risk map for political recommendations or fund allocations.

In the beginning of the ESPON Hazards project, the approach was to develop risk maps for all individual hazards but the difficulties encountered with the definition of vulnerability and the low application potential of the resulting risk maps led to the conclusion to not develop these further (see also discussion below).

As a conclusion, the development of the single hazard maps, the aggregation process as well as the development of the risk maps are an important contribution to the discussion on hazards and risk on European scale. This was the first approach to take all spatially relevant hazards into account over such a large area. In particular, the single hazard maps received substantial feedback as the results presented interesting patterns that had not previously been observed on regional scale. One of the most important aspects of displaying the hazards on this scale is to show which regions are affected by hazards and thus identify the relevant political and planning responsibilities. The maps were often criticised for showing regions as hazard prone even though only a portion of them is actually affected. This shortcoming is outweighed by their value in identifying the responsible political and planning authority.

Part 2 Development of a Decision Support Frame on climate change effects

Paper III

To effectively communicate the potential impacts of climate change on the living environment, it is necessary to understand the various processes of climate change modelling and scenario interpretation as well as the roles of the relevant stakeholders and the type of information they require. This communication process is supported by a set of tools developed in the INTERREG IIIB SEAREG project, called the Decision Support Frame (DSF). The term “frame” was chosen instead of “system”, as systems are often thought of as computerized processes. In this case it was necessary to underline that, even though computer modelling and data processing may play a vital role in decision making, the communicative part is even more important. The “frame” therefore represents an integrated approach for discussions and communication. This paper outlines the DSF, the underlying research and the process of implementation, which was carried out in close cooperation with planners and other stakeholders in the case study areas.

The DSF consists of four main pillars, each of which must be discussed thoroughly in any climate change impact assessment. Together, these pillars form the framework for a science-stakeholder dialogue, which must be understood to be a permanent learning process. The first pillar, “Modelling and GIS”, contains the climate change models and the mapping tools that display the territorial effects of climate change. Most certainly, maps are the most powerful tool to communicate the territorial effects of hazards, for example floods. Climate change impacts are based on assumptions and scenarios of future development. These kinds of maps therefore have to be treated exceptionally carefully due to the uncertainty in climate change models. Since sea level rise and subsequent changes in flood prone areas might affect, for example, existing or planned settlement areas, the information contained in these maps could be extremely sensitive.

The starting point for this work was the development of three sea level rise and storm surge scenarios for each case study area: A low case scenario, an ensemble average scenario and a high case scenario. The sea level rise scenarios were downscaled to the Baltic Sea Region from data used by the Intergovernmental Panel on Climate Change (IPCC), (Meier et al. 2006). The flood data were taken from local and regional flood statistics, using only average flood heights in order to develop moderate, conservative scenarios. By developing three different scenarios, it is possible to include the uncertainty in climate change modelling in the discussion of the results with planners. The low case scenario shows that in a time span of 100 years the sea level will not remain at its current location, i.e. it will rise to a certain small amount. The ensemble average scenario uses a larger sea level rise, and the high case shows the maximum probable increase, according to current climate change research results. It was made clear that the ensemble average does not display the most probable scenario, it is just one step between the high and the low case.

The second pillar, the “Vulnerability Assessment”, supports the understanding of local or regional vulnerabilities. Even though planners and stakeholders usually know their area very well, this tool supports the rational assessment of the vulnerability that leads to a generalized overview in a defined territory. The development of the vulnerability assessment is described in further detail in the summary of the next Paper IV below.

The third pillar is the "Discussion Platform", which is probably the most important feature of the communication process. The discussion platform is designed to lead to a common understanding of the processes involved, for example the climate change modelling, decision making, land use plan development, etc. Several experts on communication and related disciplines supervise the discussions. They are carried out in different rounds in which the involved persons are to both explain and learn more about their own perspectives as well as those of the other involved parties (Lehtonen & Peltonen 2006). These discussions have proven to be most useful in helping planners to understand what climate change modelling is and how it works, including the strengths and limitations of the models. For the involved natural scientists it has been interesting to learn what kind of information stakeholders require and how this information should be presented.

The last pillar of the DSF, the "Knowledge Base", contains all information on the subject that is freely available. The knowledge base contains, for example, summaries on the climate modelling and map making, planning and decision making. Most importantly, it contains detailed information on all case study areas. It documents the decision making processes, their obstacles and procedures. This information is important for cross-border exchange of information and can lead to mutual learning by applying best practice examples.

Paper III further on summarizes the development and application of the DSF in each of the case study areas and the main results. Some of these examples are described in more detail in the summaries of the papers below and further applications are analysed in the discussion chapter.

Paper IV

There has been extensive scientific research on the issue of vulnerability in connection with climate change and sea level rise focussing on practical application (e.g. Klein & Nicholls 1998, Nicholls 1998, Mimura & Harasawa 2000). Since the SEAREG project focussed on regional development, the vulnerability assessment was developed in close cooperation with the case study areas' stakeholders, keeping the assessment structure flexible to facilitate local and regional modifications. For example, due to the geologic structure of the Baltic Sea Region the sea level rise impacts are expected to be highly variable, having a stronger effect on the southern coasts. Only by developing the vulnerability assessment in an open process is it possible to achieve understanding and support from the stakeholder side.

The approach in developing the vulnerability assessment was to focus on "hard and soft" characteristics, i.e. physical impacts and coping capacity, respectively. There is no preferred chronological order to be followed. The assessment can be carried out incrementally, varying from simple overviews to detailed assessments. The vulnerability assessment should be dynamic to incorporate new data or model calculations as they become available.

The core of the assessment is the screening and impact assessment tables, the latter one modified after Nicholls (1998). Land use types, infrastructure and economical sectors are analysed in tables, according to the effects that sea level and flood prone area changes might have on them. This sector-wise approach leads to a better understanding of the potential impacts of climate change on a region. A distinction was made between areas that will be permanently under water due to rising sea level and those that will be affected by flooding during storm surges. The main obstacle was the long time frame of the scenarios (100 years), as many stakeholder decisions are taken on short-term basis. On the other hand, many planners said that a 100 year perspective was a very appropriate one, since the factor of sustainability of investments was very important, for example when designing and building new infrastructure.

In general the vulnerability assessment and the way it was applied, as well as the differentiation between hard and soft factors and different sea level rise impacts was well received on the stakeholder side. The main benefit for the stakeholder was the additional information that such a matrix based approach gave on the structure of a region, as structural information plays an important role in the discussion of mitigation and adaptation strategies.

Paper V

The first time the SEAREG project was directly asked to contribute to a scientific publication was after being invited to a key note speech at a EU-Workshop entitled "Towards an Integrated Management of Soil and Water Resources: Fate and Behaviour of Pollutants" in June 2004 in Bonn, Germany. Although the SEAREG project did not focus on soil contamination directly, planners and stakeholders in several case study areas had mentioned it, most explicitly in Gdansk and Pärnu. The main concern was the behaviour of pollutants in salty or brackish water as a result of temporary or permanent inundation of contaminated sites. The SEAREG project had not allocated any funds for research on soil contamination. Further, the project partners in Poland and Estonia were in the unfortunate situation of not to receive any co-funding for their project activities. As a result, the soil contamination assessments remained on a theoretical basis during the application of the DSF, i.e. it was assessed exemplarily based on few data sets from earlier soil sampling results. At the time of this publication, the possible effects of sea level rise were still being discussed with local experts and stakeholders and local thematic data were not yet available. During the later development of the project, the Polish Geological Institute (PGI) and the City Council of Pärnu were able to provide some data and maps with information on potential sources of soil contamination, as well as some data and maps showing areas of topsoil heavy metal concentrations. Some of these data were overlain with sea level rise scenarios and discussed in the DSF applications (Staudt et al. 2006 and Klein et al. 2006).

This paper focuses mainly on the first stages of development of the "Modelling and GIS" part of the DSF. It displays the first digital elevation models (DEM) and their overlay with sea level rise and storm surge data. These presentations were then further developed during the course of the SEAREG project and the development of the DSF.

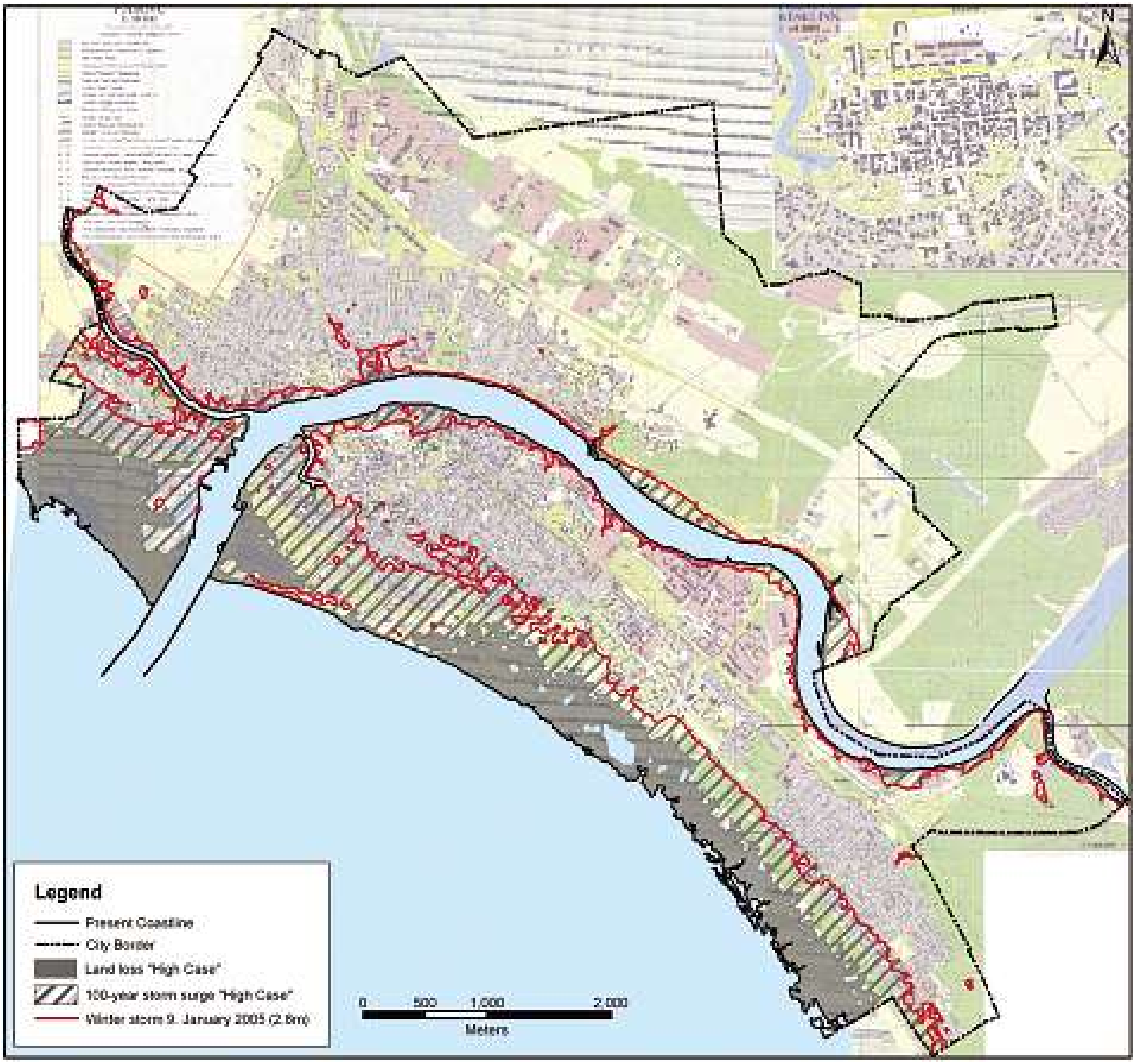
Gdansk is located on the banks of the Vistula River on the Baltic Sea coast. The city itself is partly very low lying and it is currently protected by some sea walls and dune structures. The old course of the Vistula River through the centre of the old town was relocated outside of the city to lessen the river's flood hazard. The old riverbed is still visible in the city's morphology and is nowadays partly used as canals. The entire area experiences a slight land subsidence, which increases the impact of sea level rise. The hinterland of the city is hilly. In recent years, these hills have been the source of water that caused flash floods after heavy rain falls, inundating parts of the city. Gdansk might also face a real flooding problem from storm surges, as a higher sea level leads to higher floods. If such a storm also provoked flash floods from the hills, the city would be in a difficult situation caught between two flood sources.

For the Gdansk case study, sea level rise maps and overlays with potentially contaminated sites provided an important input to the development of the vulnerability assessment. This was of particular importance, as initially obtaining stakeholder cooperation in this case study area was challenging. Once the first maps showing the territorial extent of low lying areas and potential impacts of sea level rise were presented, the willingness to cooperate improved considerably. By then it had not been possible to develop the vulnerability assessment tables for the Gdansk region, but these first maps raised a high interest and it became possible to extend the development of the DSF with an increased number of stakeholders. The first versions of the vulnerability tables are shown in Paper VI (summarized below), the final versions are presented in Staudt et al. 2006.

The morphology of the Pärnu study area is characterized by a subtle relief and its average elevation is low. The Pärnu River, which is slow flowing and meandering, divides the town into two parts. The old town is located on a peninsula between the river and the sea. The town of Pärnu has experienced several storm surges in the past. The impact of these storm surges leads to simultaneous river floods because the incoming sea pushes the slowly running river water back, thus flooding the hinterland. The SEAREG project decided to take only moderate flood levels into account in the maps displaying sea level rise scenarios and storm surge floods. Although only moderate flood levels were used, large parts of the town appear to be flood prone. It was the aim of the SEAREG project to show what future water levels are possible. These initial sea level rise scenario maps of the Pärnu case study area provoked harsh reactions, such as "horror scenarios to scare local people" by some stakeholders and climate change experts. The winter storm of January 2005 was an extreme weather event that cannot necessarily be attributed to be a result of climate change. However, this storm caused record flood levels in Pärnu. Interestingly, this flood level was equally high as the projections in the high case scenario of the SEAREG project (see map 1). This shows that the scenarios described here are rather conservative and probably underestimate potential future storm surges. Since the storm surge of 2005 is considered as an extreme event, the scenarios for the town were not changed but the interest of the town government to participate in the development of the DSF and the development of adaptation strategies rose considerably (see also discussion below). Klein et al. 2006 discuss the final versions of the sea level change scenario maps and a vulnerability assessment for the Pärnu area.

Paper VI

The paper presents the further development of the Decision Support Frame (DSF) of the SEAREG project through specific examples from the case studies, including several figures and maps of the Gdansk area that display the potential impact of flood related hazards



Map 1. High case sea level rise scenario and storm surge flood in Pärnu Town. Modified after Schmidt-Thomé et al. 2005 (Paper IV). Map designed by Johannes Klein, Geological Survey of Finland.

on the city, as well as the actual land subsidence which amounts to 1–2mm per year. The preliminary results of the Gdansk case study area were already discussed in the summary of the paper above. The observed sea level rise over the last 100 years has been of around 1.5mm/year, raising great concerns for future development, especially if there is accelerated sea level rise. As an addition to the Paper V discussed above, this paper presents the application of a discussion round with planners in the Gdansk area. As a result, the vulnerability assessment is presented in tables analysing the impact for areas that may be either permanently or temporarily flooded in the future.

The paper concludes that the areas of greatest concern, in terms of the impact of changing sea and flood levels, are all beach areas of the city. This is of particular interest for the tourist sector, and industrial facilities in low lying areas, especially those behind embankments lower than one meter. Further, shallow aquifers along the coastline may be subject to sea water intrusion. These conclusions were reached with the stakeholders and have led to positive feedback. The most senior planning officials for the Gdansk area have participated in the further development of the DSF process. A direct result of this positive cooperation has been a continuation of the work in the SEAREG's BSR INTERREG IIIB follow-up project "Developing Policies and Adaptation Strategies to Climate Change in the Baltic Sea Region" (ASTRA).

The first part of the paper describes the application of the DSF in the greater Stockholm area. According to the sea level rise scenarios developed during the SEAREG project, Stockholm will not be affected by sea level rise to any great extent in the next century. This is mainly due to two facts. Firstly the isostatic rise of the land, which amounts to some mm per year. The second reason is the protected location of the city: Since westerly winds prevail, most storm surges affect western coastlines of Sweden and the eastern coast is generally better protected. In the rare case of a storm from the east, the surrounding islands would block heavy wave action.

Although sea level rise does not cause great concern, there might be increased floods from Lake Mälaren, the other water body Stockholm is located at. In fact, the old town of Stockholm is the point where most of this large lake's water discharges into the Baltic Sea. The lake is of great importance to Stockholm and the entire region as the major source of drinking water. Recreational use of the lake and its shorelines are also relatively important.

Due to climate change, the main runoff patterns of the Lake Mälaren might change and thus lead to floods from the lake side. The lake has had strong seasonal water level fluctuations that, until 1943, led to flooding. Sea locks were then built to regulate the runoff and manage the water level of the lake. Since then the lake level has been quite stable, as both low and high water levels could be avoided. However, in the case of high discharge from the lake, the current sea locks cannot be opened wide enough to prevent flooding. If these high peaks of lake water discharge increase, the flood hazard from the lake would also increase. These results of the SEAREG project were discussed at several seminars and meetings with stakeholders from the greater Stockholm area. The need to reconstruct the sea locks has for long been under consideration by the City of Stockholm. The application of the DSF in the Stockholm case study area has led to an enhanced understanding among stakeholders, that the increased runoff should be taken into account in the new design of the sea locks.

This direct result of the SEAREG project is probably one of the best examples how stakeholder oriented communication can lead to a better understanding of natural hazards and the impact of climate change on them, and a consequent inclusion of such results in the development of future land use plans.

DISCUSSION

Hazard and risk, the challenge of terminology

The terminology used in hazard and risk community is not yet standardized and there are several definitions of the terms. In the course of the projects that form the basis of this study, the terms hazards, vulnerability and risk, as well as many other were defined and finally summarized in a paper entitled "Technical Glossary of a Multi-hazard Related Vulnerability and Risk Assessment Language" (Schmidt-Thomé et al. 2006a). The research work carried out to compile this glossary confirmed the complications that may arise from the many definitions used in the hazard and risk community. Sometimes the definitions are quite close to each other but often there are substantial differences. Therefore, it was decided to let several definitions stand side by side and let the user of the glossary decide which definition suits the envisaged purpose best. The research community that was asked to review the glossary received this approach rather positively. Several scientists who had worked for a long time with a certain definition for one term were not willing to change their definition but could accept the chosen multi-definition approach.

This study adopts a similar approach, as it does not aim at defining vulnerability and risk from a theoretical perspective, but rather seeks to achieve global understanding. The terms are defined on the basis of a discussion processes that focussed on the applicability of the terms to spatial planning. The goal is to communicate which natural hazards potentially affect an area, what are the damage potential (vulnerability in a broad sense) and resulting risks. Finally, which of this information is important for spatial planning.

Natural extreme events and natural processes

In the assessment of natural hazards, it has to be kept in mind that all, so-called, natural hazards are natural phenomena that only turn into a hazard when human beings or assets are affected. Nature itself is not threatened by natural hazards, and nature has always adapted itself to natural catastrophes. Many natural hazards have, in some cases, even contributed to many site-specific natural advantages that human beings depend on, e.g. fertile soils in flood plains. It has to be accepted that natural hazards are part of our living environment and that they cannot be fully mitigated. Human beings have to adapt to them and organize their living environment and settlement locations as safely as possible, taking natural hazards into account.

The next step is to identify and define what are natural hazards and how they might be influenced by climate change. It is important to distinguish between natural hazards, which are extreme events, and natural processes, which are permanent or long-lasting. Natural processes might lead to adverse conditions for the living environment, from the human perspective, but should not be understood as natural hazards. Therefore in this study, the definition of hazards differentiates between *processes* that might lead to adverse situations, and *events* that are natural hazards.

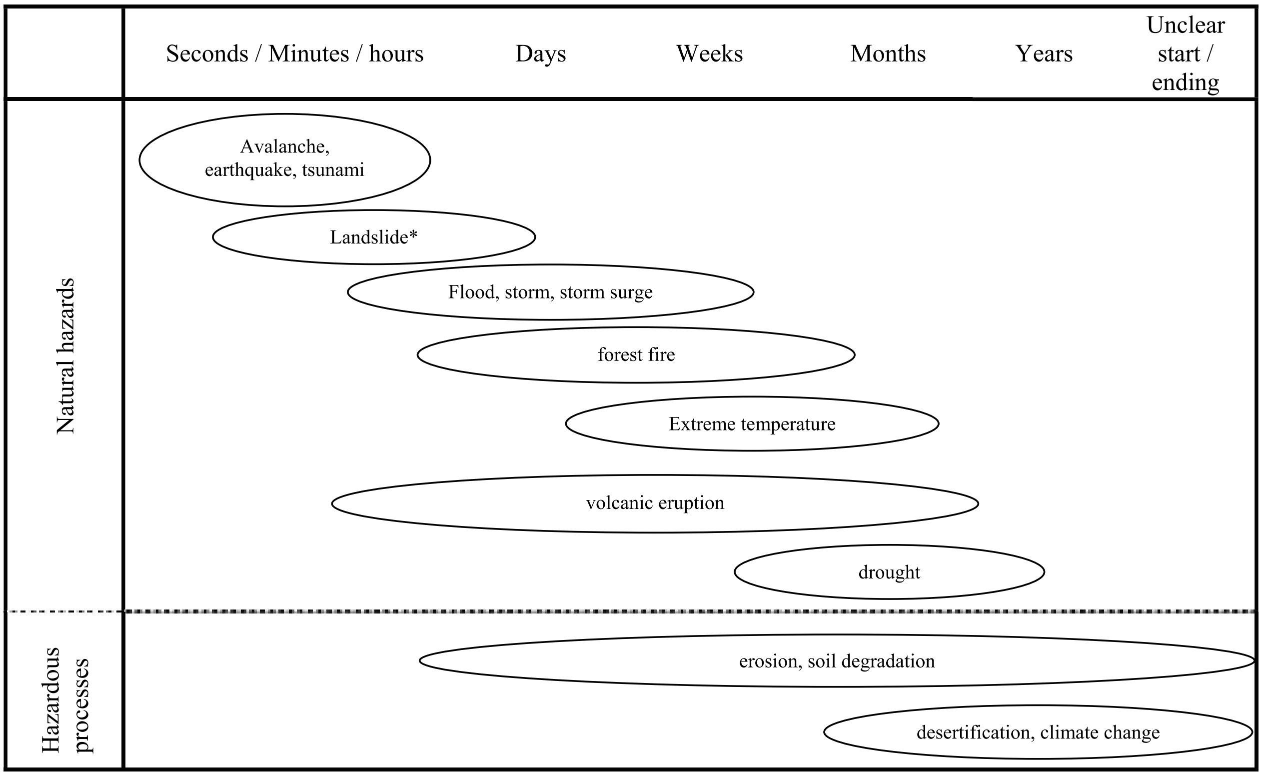
This distinction between natural hazards and natural processes is made too seldom. For example, erosion, soil degradation and even mining accidents, the latter one in fact belonging to technological hazards, are sometimes included in natural hazard research projects. At the same time, several other natural hazards are often not considered at all (e.g. Masure 2001, Lilljequist & Ligtenberg 2005). In the course of the projects that form the basis of this study, it became clear that a definition of natural hazards is vital, in order to focus the scope of research and resulting recommendations appropriately.

This study defines natural hazards as natural extreme events. Extreme event means that a normal, relatively constant, or constantly repeated situation is disturbed or changed for a matter of seconds, days, weeks or months, after which the initial "normal" state is reached again. The duration of a natural extreme event, i.e. a natural hazard, varies between seconds and months. For example, an earthquake is a motion ofa normally stable ground that lasts for seconds or minutes, after which the stable situation is reached again. There are many ground motions that are not felt by human beings, but only recorded by seismographs. Since most of these ground motions, which in some regions are rather frequent, do not cause any damage they are not considered as natural hazards but belong to the relatively stable "normal" situation. Other hazards last longer, for example, droughts. Droughts are determined by a comparison to normalized long-term average of, e.g. soil humidity, river runoff or precipitation of a defined season or year. Droughts may last several months or even years, but are usually terminated by changing weather conditions, e.g. rainy seasons, at some point. In this sense it is possible to categorise all natural hazards into average times of duration, which is the main character that distinguishes them from natural processes (see figure 1).

Natural processes are natural phenomena that are ongoing. They might sometimes change but usually it is difficult or impossible to define their exact beginning and end. Natural processes might be influenced by hazards. For example, a storm surge, which is an extreme event, might lead to severe coastal erosion. Coastal erosion is an ongoing process and, in the case of severe erosion, the storm surge functions as the hazard. Erosion is the process that is affected by the hazard. Also climate change is a process, as there is no clear understanding when it has started and when it stops, especially as climate has always changed in geological time. The human induced climate change, as well as its potential effects on the frequency and/or the intensity of natural hazards is currently under intensive scientific discussion (e.g. Bärring & Persson 2006, McBean & Henstra 2003, Emanuel 2005, Trenberth 2005).

It is important to distinguish between processes and events, not only to be scientifically accurate, but also for practical reasons. As mentioned above, climate change and its impacts are currently widely discussed, and often climate change is addressed as a natural hazard. It should be kept in mind that natural hazards, especially the hydro-meteorological ones, result from weather conditions, not from the climate. The climate may change over longer time periods and might thus influence the basic conditions under which hydro-meteorological hazards occur. In other words, the climate change influences the framework of some natural hazards but it is not a hazard itself. It is a permanent process and it should be dealt with accordingly.

In the analysis of hazards, one should first assess which kind of hazards affect an area and then, how these hazards may be influenced by climate change. As discussed above, the impacts of climate change on hazards are being studied and, even though some trends might be visible, there is no statistical evidence to prove its impact. It is also still being discussed whether climate change affects the frequency or magnitude, or both, of natural hazards (e.g. Bärring &Persson 2006, Emanuel 2005). In other processes, such as the above-mentioned coastal erosion, the differentiation of processes and hazards is also helpful. The measurements that should be taken against ongoing erosion processes are different from those that protect a beach from a storm surge. Also, a storm surge might have several other impacts on a region in addition to coastal erosion, e.g. flooding and wind damage. Even though both processes and hazards can have adverse impacts on a region's development, it is important to distinguish between the need for permanent protection or mitigation measures of processes and means that are useful against extreme events. In



*Including all kinds of mass movements, cavity collapses and ground failures. Eventually some mass movements can continue for years but could then be seen as processes

Figure 1: Hazardous natural phenomena and their potential length of duration

ideal cases, strategies can be combined, but generally the planning for hazards should have a larger scope than planning for processes.

Figure 1 summarizes the discussion above. It displays examples of the average length of natural phenomena and processes that are considered as hazardous. The distinction between natural hazards and natural processes is made by measurable and/or foreseeable start or ending times.

It must be kept in mind that natural hazards and natural processes, as well as their impacts, are sometimes not purely natural, as human beings influence both natural hazards and natural phenomena that might lead to hazardous situations. In the context of natural hazards probably the best example are forest fires. Most of the forest fires in the Mediterranean region are caused by human influence, e.g. accidents, while natural sources, such as lightning, play a minor role (Goldammer & Mutch 2001). In the role of processes, certainly one of the most important discussions is the one of human induced climate change. Meanwhile some say that a changing climate is normal and belongs to natural processes, there are indications that the recent rapid climate change is influenced by green house gas emissions caused by human activities (e.g. Berner & Streiff 2000, Rahmstorf & Schellnhuber 2006, Schellnhuber et al. 2006).

There are several natural hazards that can affect the lives and assets of human beings, but not all of these natural hazards are of relevance for spatial planners. It is basically impossible, or useless, to include the effect of a potential meteorite impact into spatial planning. In order to identify those hazards that are spatially relevant, i.e. of concern for spatial planning, a spatial filter was developed and applied by the ESPON Hazards project (Fleischhauer 2006). Eleven natural hazards were identified as spatially relevant and are summarized in table 1 below.

The next step is to analyse the potential of climate change to influence natural hazards. This leads to a distinction of natural hazards into two groups: Those that are potentially affected by climate change and those that are not. There are several different approaches to categorise natural hazards into subgroups (e.g. Anderson 2003, McBean & Henstra 2003, Federal Office for Spatial Development 2006). The spatially relevant natural hazards identified by Fleischhauer (2006) are here categorized into geo-hazards and hydro-meteorological hazards: Geo-hazards are those hazards that are only or mainly influenced by seismic

Table 1: Categorisation of spatially relevant natural hazards

Natural hazards		Affected by climate change
Geo-hazards	Earthquakes	No
	Tsunamis	
	Volcanic eruptions	
	Landslides*	Yes
Hydro-meteorological hazards	Avalanche	
	Drought	
	Extreme temperature	
	Flood	
	Forest fire	
	Storms	
	Storm surges	

*Including all kinds of mass movements, cavity collapses and ground failures
Source: Modified after Schmidt-Thomé 2005

and geological factors, i.e. earthquakes, tsunamis, volcanic eruptions and landslides. Geo-hazards occur usually rather infrequently and are difficult to predict. Except for landslides, the source of which can be mitigated to certain extent, geo-hazards are also basically impossible to prevent (WBGU 1998). Hydro-meteorological hazards are the remaining seven spatially relevant natural hazards. The table below categorises the spatially relevant natural hazards into geo-hazards and hydro-meteorological hazards and distinguishes those that are potentially influenced by climate change.

In general, it can be stated that all hazards that are of hydro-meteorological origin are potentially affected by climate change, meanwhile geo-hazards are generally not influenced. The only exception are landslides, as they can be caused by, for example, extreme rainfall, also on slopes that are usually considered as stable, or on river embankments, in case of high floods.

Vulnerability and risk

The term "vulnerability" plays a crucial role in the discussion on risk, as it is the variable that adjusts the relationship of the probability of occurrence of a hazard and the damage, which is the resulting risk. There have been several approaches to finding appropriate, internationally accepted definitions of the terms vulnerability and risk but there is still no common understanding of these terms yet (e.g. Schmidt-Thomé et al. 2006a, Cutter 1996). As discussed above, natural hazards are natural phenomena that do not put nature at risk. Vulnerability and risk represent a purely human perspective. In simple terms, human beings are vulnerable to natural hazards, as they might be injured or killed and their assets might be destroyed. Human beings put themselves at risk by their presence in a naturally hazardous area. In this study, risk is defined as a function of a hazard (or multi-hazards) and vulnerability. In other words, risk is dependent on the intensity of a hazard and the potential extent of damage. The key challenge is thus to understand and control or influence the main driving forces behind risk, i.e. hazard and vulnerability. This basic assumption should be generally understood and accepted.

Humans have always been under potential threat from natural hazards, and the decision to live in hazardous areas was taken consciously, at least at some point, e.g. when settlements have been rebuilt after disasters, and consequently a certain risk has deliberately been accepted from then on. Depending on the geographical, geologic and climatic conditions, human settlements have been exposed to different natural hazards, as well as different hazard intensities and frequencies. These regional differences in natural hazards have led to different perceptions of both the vulnerability and risk in different cultures. In areas where natural hazards strike more frequently, the "acceptable risk" is different than in areas that seldom experience hazards. The perceptions of vulnerability and risk are therefore based on the different natural, social and cultural contexts of understanding the terms, and consequently there are differences in defining the variables to measure them.

The vulnerability assessment, which forms part of the Decision Support Frame (DSF) developed in the course of the SEAREG project, focuses on sensitising planners and stakeholders to the implications and possible impacts of a changing climate (Papers III and IV). Because of natural and cultural differences among regions, this vulnerability assessment is kept as simple and as flexible as possible, as each study area where it might be applied has unique characteristics. It is a tool to better understand potentially affected areas and resulting risks, to communicate and sensitise it, and finally support the development of appropriate adaptation strategies. Since the vulnerability assessment approach was developed in close cooperation with stakeholders, the acceptance of it was very high. Most planners stated that they were very much aware of the risks in their respective regions, and that they would not need a vulnerability assessment. When the work started, many planners said that the display of hazards, and climate change impacts in maps would be sufficient. The acceptance of the vulnerability assessment grew as it became clear that it could be used as a tool to support a step-wise approach that facilitates communication. The key to the vulnerability assessment, within the DSF, is that it is transparent. Each step in the assessment can be easily traced back, which ensures a broad understanding and comprehensibility of both the process and the results.

In the process of developing and applying the DSF with practitioners and stakeholders, it turned out that clear scientific definitions of vulnerability and risk were not necessary, as the terms were understood based on common sense. In other words, theory based definitions might have led to a more scientifically sound version of the vulnerability assessment, but applying this appeared difficult as five different languages and cultures were involved in the process. The chosen approach was practical and process-oriented, which eased the communication with and among stakeholders instead of making it challenging and difficult. This does not argue against finding and developing clear, scientifically sound and internationally accepted definitions. As long as the process of defining terms is still ongoing, it proved out to be more practical to use common understanding and clarify the terms in cases of misunderstandings. The discussion platform of the DSF (Paper III, Lehtonen & Peltonen 2006) proved to be an excellent tool to discuss the meanings of terms among all involved scientists and stakeholders. It was always made clear that the DSF is an open-ended process, and that terms should be defined by those who actually use and need them. The scientists played the role of delivering the background interpretation of data and communicating it to the stakeholders that have to make the decisions on appropriate mitigation and adaptation strategies.

Single and multi-hazard maps for spatial planning

This section discusses some possibilities of displaying natural hazards and climate change effects in maps, as well as the challenges of displaying vulnerability and risk in maps. The discussion is based on practical experience with planners and stakeholders.

One of the most effective tools to display natural hazards and climate change impacts are maps that show the extent of the affected territory. Since maps usually display only a two-dimensional, simplified part of the reality, the scope and the target of hazard maps has to be clearly defined. Spatial planners use maps on a daily basis, for example in land use plans, but natural hazards and climate change impacts are thematic information that is not necessarily available to many planners and other stakeholders. Therefore hazard maps have to be handled with great care, especially when containing sensitive information. This does not mean that hazard information should be classified. This means that the way of presenting the data, the legend and explanatory notes on maps has to be selected carefully in order to avoid misunderstandings. Many of the above described national strategies on climate change adaptation call for a broad participation of stakeholders and strong cooperation between different actors. Therefore the process of communication must be understandable and comprehensible to all involved.

There are several possibilities for displaying natural hazards in maps, e.g. showing the territorial extension, the magnitude, frequency etc. There is no international agreed way of representing hazards in maps, nor a standardised legend. It is therefore of utmost importance to clearly define the purpose and the scope of each hazard map. Many natural hazards have local impacts, the extent of which can be delineated rather exactly (e.g. landslides), while other hazards affect larger areas and it is more difficult to delineate their territorial extent (e.g. droughts). For measuring the extent and or impact of a particular natural hazard, single hazard maps are used by planners to delineate, e.g. areas with landuse restrictions (e.g. Jarva & Virkki 2006, Wanczura, S. 2006).

As discussed above, it is recommended that a multi-hazard approach is included in planning: To first analyse all potential hazards in an area and then later to decide which hazards can be excluded. Once some hazards are excluded, it is of importance to develop both single hazard maps as well as multi-hazards (synthesized) maps. Multi-hazard maps are extremely useful in giving an integrated overview on hazards in a study area. The aggregation of hazards into multi-hazards maps is a challenging task, and the intended purpose must be clear. Since all natural hazards vary in how they are measured, many cannot be combined and a simple aggregation of variables into a single legend is basically not possible. It is therefore necessary to categorize the single hazards into classes. These classes could follow a simple classification, for example ranging from "no hazards" to "high level of hazards". The exact class determination has to be evaluated based on the area and the purpose of the maps. The prime target of multi-hazards maps is to support land use restrictions at an early stage. For example, areas identified as highly (multi) hazardous should be excluded from vulnerable landuse types, e.g. housing and schools. Areas with less multi-hazards or lower classes of multi-hazards should then be assessed more carefully, taking also the single hazard maps into account. Planned landuse can then be adjusted appropriately, e.g. by building codes. Finally, multi-hazards maps can also support the allocation of special funds to support adaptation in areas with multi-hazards.

A concrete recent example of the application of multi-hazards maps comes from the aftermath of the tsunami that struck the Indian Ocean in 2004. During the international seminar on tsunami – "How Thailand and neighbouring countries will become ready for tsunami" in the beginning of 2005 in Bangkok, some speakers argued that only relocation can ensure future safety for citizens in the entire region, especially in most affected areas. Most participants of the seminar, including members of the Thai government, opposed this approach because it would greatly disturb citizens and the regional economic activities, for example tourism. If rebuilding hotels and bungalows was not allowed close to the beach but only in the hinterland, it would be most probable that tourists would not visit these areas any longer. This might lead to long lasting political and social problems. It is very probable that a significant tsunami will not strike the area for many years, therefore local decision makers might eventually allow new hotels to be built near the beach. This would lead to conflicts with those hotel owners that were initially forced to build their hotels further inland. Therefore the relocation proposal was strongly rejected at this seminar. On the other hand it was clearly understood that vital installations, such as rescue and disaster management facilities should be located in tsunami proof areas. It should also be insured that these vital installations are secure in the event of other natural hazards. In order to find appropriate locations, multi-hazards maps were discussed as one of the most appropriate tools. They enable the definition of highly hazardous areas and those with less and even no hazards. Another good example for such maps was developed by a German – Indonesian technical cooperation project on mitigation of geohazards. In this study area, which is also tsunami prone, single hazard maps have been aggregated into multi-hazards maps, and then used in local land use plans. The project strongly involves local stakeholders and the public in order to define local vulnerabilities and take appropriate land use decisions (Effendi et al. 2004).

Vulnerability and risk maps for spatial planning?

The European Commission (2004, 2006) and the Munich Reinsurance Company (2004) among others, call for the integration of vulnerability and risk concepts into spatial planning. Such integration is current practice only in France (Fleischhauer 2006a, Greiving 2006) and wider application would contribute to more sustainable planning practices. To support such development, it has to be carefully assessed how vulnerability and risk are measured and assessed and how this information can be used by spatial planners.

The crucial question is how to represent vulnerability and risk in maps, as it is very important to ensure understanding and comprehensibility in the stakeholder communication process. Hazard maps are complex, so that any additional information will complicate the interpretation even more. As mentioned above, there is no standardised definition of vulnerability or risk, and therefore it is even more difficult to add these data in maps. If a common understanding on the variables to measure vulnerability cannot be found, the stakeholder dialogue will be very difficult. The same accounts for risk maps, which are based on the combination of vulnerability and hazard.

In the case of the European wide hazard and risk maps, the potential and limitations of the maps were outlined precisely in the final report of the ESPON Hazards project (Schmidt-Thomé 2005). The single hazard maps, that display the hazards at the level of regions, can be used to identify which regions are affected by which hazards in order to show regional hazard typologies and corresponding responsibilities for hazard assessment. It was clearly underlined that the applicability of the maps is only on European scale as a detailed hazard assessment can only be carried out locally. A downscaling and analysis of the results of the ESPON Hazards project into a single country (Finland) showed that generally many of the results were correct but that the further assessment and corrections of the data are necessary (Schmidt-Thomé 2005a). Climate change was integrated into some of the hydro-meteorological hazard maps as an overlay, in order to point out areas that might see an increase of natural hazard frequencies in the future. The further development of multi (aggregated) hazard maps had several limitations, as the included hazards were not simply added up but aggregated by a weighting system based on expert opinions. The application of the weighting system was generally accepted but faced also some criticism, as the hazards were weighted from a European and not a local perspective, so that many regions did not agree on the resulting hazard pattern. Nevertheless, the overall aggregated hazard pattern on the ESPON territory was accepted as a valuable first approach for showing the general distribution and regional typologies of hazards. The economic risk maps were based on a very simple vulnerability approach (GDP per capita and population density). They delivered information on the distribution of risks, especially concerning the risk typologies based on hazard and vulnerability intensity (Paper I). The analysis of these maps by experts on regional development proved to be challenging, because it could not be decided whether this approach of vulnerability was appropriate or not. Ethical reasons played a strong role, less rich regions are considered less vulnerable than richer regions. This could not be accepted, especially by the less rich countries. It was then decided to develop a broader approach. The compromise was to take the best available data on integrated vulnerability and add more aspects to the economic vulnerability (Kumpulainen 2006). This approach was not really successful either, as it was rather complex and many experts had great difficulty in analysing the complex map. This complexity certainly grew when the vulnerability was combined with the aggregated hazards in the development of risk maps. The risk patterns and typologies could certainly be analysed by the experts involved in the development of the maps, but it proved to be extremely difficult for people not directly involved to make sense of them. Consequently, the data sets and maps that were used and applied by ESPON were the single hazard maps and sometimes the aggregated hazards map. The vulnerability and risk approaches proved to be important in the scientific dialogue but with limited practical application.

The European Commission has specified the integration of risk prevention into the European Regional Development Fund (ERDF) structures 2007–2013 (European Commission 2004, 2006). The single natural hazard maps were therefore further developed to identify areas and regions in Europe where certain hazards could be further studied in future ERDF activities such as regional development fund projects (Schmidt-Thomé et al. 2006). Neither the vulnerability nor the risk concepts were recommended for this purpose as they were too complex. Instead, it was decided that vulnerability and risk should be examined, case-wise, at the local level to decide which kind of hazard related projects are relevant for the respective regional development.

The integration of vulnerability and risk into planning maps is also critical in regional and local maps, since planning is mostly concerned with future activities. Vulnerability and risk maps show a static picture of the current situation and it is therefore challenging to use such information in maps when discussing, e.g. future land use plans. A change in the land use will most probably lead to a change in the vulnerability and a change in the risk. For example, areas currently declared as brownfields will most probably appear to have a very low vulnerability, and consequently a low risk, in such maps. However, the vulnerability would dramatically change once these brownfields are reclaimed and then converted into housing areas. In such a case it would theoretically be possible to create scenario risk maps, but it is likely that they are of limited use in daily planning practice. The huge challenge is that vulnerability and risk maps add many additional variables to land use and hazard maps. It might well be that the readability, and therefore the comprehensibility, as well as the potential acceptance among stakeholders, declines proportionally with the addition of data (see also summary of Paper II, above). Since it is proposed to not only take multi-hazards but also climate change into account in spatial planning, it has to be recognized that climate change scenarios are based on assumptions about global economic development and future greenhouse gas emissions (Church et al. 2001). The large grid cells these models are using make it difficult to downscale them to an appropriate local scale. To create local risk scenario maps that capture future land use change, and combine these with information on climate change impacts, implies that several kinds of scenario data would be combined. It is questionable if this kind of information is scientifically sound and acceptable for decision making processes. It should therefore be considered very carefully if vulnerability maps are needed at all, and if they were required, what kind of information should be used.

A general lesson from the ESPON Hazards and SEAREG projects, as well as other research activities, is that planners do not necessarily require vulnerability and risk maps. In the case of the SEAREG project, planners and stakeholders were satisfied with simple overlays of future flood prone areas on current land use maps. The vulnerability of the area was assessed with the help of the vulnerability assessment (e.g. Staudt et al 2006, Virkki et al 2006). The combination of sea level and flood prone area changes delivered sufficient information for the local planners to consider the potential impacts of climate change in future land use plans. In the case of Pärnu (Estonia) the sea level and flood prone area changes were overlaid with land use data, for example on economic sectors (e.g. Klein & Staudt 2006). Experience gained in the SEAREG follow up project, ASTRA, showed that these overlays have been used in the decision making process by the Town Council and the Town Government of Pärnu. In the matter of designing future storm surge protection measures on the riverbanks and the shoreline, the Town Council had proposed to start with "raising the ground surface on shorelines and riverbanks" for flood protection in the beginning of 2006 (Pärnu Town Government 2006). The Pärnu Town Government did not accept this proposal and signed a decision, stating that "in further flood protection activities changing flood patterns should be taken into account". They identified the ASTRA project as the basis for this decision (Pärnu Town Government 2006). This example shows that natural hazard and climate change data were useful in maps, and the vulnerability issues could be assessed with the help of additional tools, such as the discussion platforms and the vulnerability assessment of the DSF.

Risk maps do find application in some special sectors of planning or when making very specific decisions. For example, they can help to identify areas that have such a high risk that either restructuring or relocation are necessary (Greiving 2006). Vulnerability maps are also useful in special sectors, e.g. in emergency preparedness planning. Rescue services need to know how many people are located in which parts of a town during day and night time and how far to the nearest fire stations and hospitals (Krisp & Karasová 2005). An additional factor that has to be taken into account in the development of vulnerabilities and risks is that some factors change hourly, daily and seasonally. Vulnerability and risk depend on and change with, forexample, teaching times at school, the number of job commuters at a certain time of the day, or the number of people at large events, such as concerts.

Natural (and technological) hazards are partly influenced by weather conditions that can change rapidly. Seasons are also important, for example because of the meteorological conditions and holidays. All of these factors should be taken into account in vulnerability and risk estimations and it is therefore challenging to decide which parameters could be used in map applications. In other words, specific, sector wise risk maps can be very useful, while general vulnerability and risk maps might complicate the stakeholder communication process.

CONCLUSIONS

Integrating hazard, climate change and risk concepts into regional development and spatial planning has proven to be relevant to spatial planners. Time should be taken to define all potential natural hazards and processes affecting a region, as individual mitigation or adaptation strategies for each hazard are different, even though they can be eventually combined. It was shown that natural hazard maps and overlays with climate change impacts have led to an enhanced understanding of future potential threats to spatial development and that vulnerability concepts are a valuable tool to assess risks. The multi-hazard concept is challenging but important, as it is vital for spatial planners to obtain information on all kinds of potentially adverse impacts. One of the most important aspects is the communication process, as hazard data are very complicated and broad acceptance for decisions can only be achieved through understandable and comprehensive sources of information. The aspects of vulnerability and risk are more critical. It should be left for spatial planners and other stakeholders to carefully consider and decide if they need those concepts and corresponding data, and if they do, what is the specific purpose of such maps and what variables should be used to measure vulnerability and risk. It is important that the vulnerability assessment goes beyond the impact of hazards and climate change, as risk also arise from other sources such as local economic dependencies on, e.g. traffic. The vulnerability and risk analyses should aim at lowering the vulnerability in order to lessen the risks of hazards. Finally, the following points are recommended in hazard and climate change related spatial planning activities:

- Further integrate natural hazard approaches in spatial planning and open the process to all involved stakeholders
- Broaden the scope and move towards integrated multi-hazard assessments to identify all potential hazards of an area.
- Integrate climate change scenarios in the (multi) hazard assessment to identify potential changes in hazard patterns
- Ensure inter-disciplinary, inter-regional and inter-governmental cooperation to obtain multi-dimensional views.
- Integrate vulnerability assessments and identify all variables that contribute to specific vulnerability patterns
- Analyse the vulnerability aspect in natural hazard and climate change risk as it is the easiest starting point for adaptation processes
- Generally anticipate higher importance for hazard and climate change adaptation and less for mitigation

It certainly has to be recognised that these bullet points are maximum demands or claims for action. Many planning and decision making practices have developed over decades and have been operating successfully. The point of these recommendations is not to criticize or change any spatial planning practices, but to assist in the development of ideas for improvements. It was shown that natural hazards are now of increasing importance in Europe and worldwide. Along with the growing importance of natural hazards (and the potential effects of climate change on these) are the financial impacts and societal perceptions of risk. The current paradigm shift in the weighting of importance from hazard and climate change mitigation towards adaptation, calls for the integration of spatial planning into the development of related strategies. The organization of land use and the distribution of spatial functions can definitely support adaptation strategies and lead to a better protection of the living environment. The development of appropriate adaptation strategies is a slow process that should integrate all relevant actors and stakeholders. The aspects discussed here could contribute and shed light on some aspects of this process.

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